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(54) **LIQUID COOLED RACK INFORMATION HANDLING SYSTEM HAVING STORAGE DRIVE CARRIER FOR LEAK CONTAINMENT AND VIBRATION MITIGATION**

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(22) Filed: **Jan. 4, 2019**

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(51) **Int. Cl.**
H05K 7/20 (2006.01)
G06F 1/20 (2006.01)

(52) **U.S. Cl.**
CPC ***H05K 7/20836*** (2013.01); ***H05K 7/2079*** (2013.01); ***H05K 7/20763*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 23/473; H05K 7/20836; H05K 7/20781; H05K 7/2079; H05K 7/20809;
(Continued)

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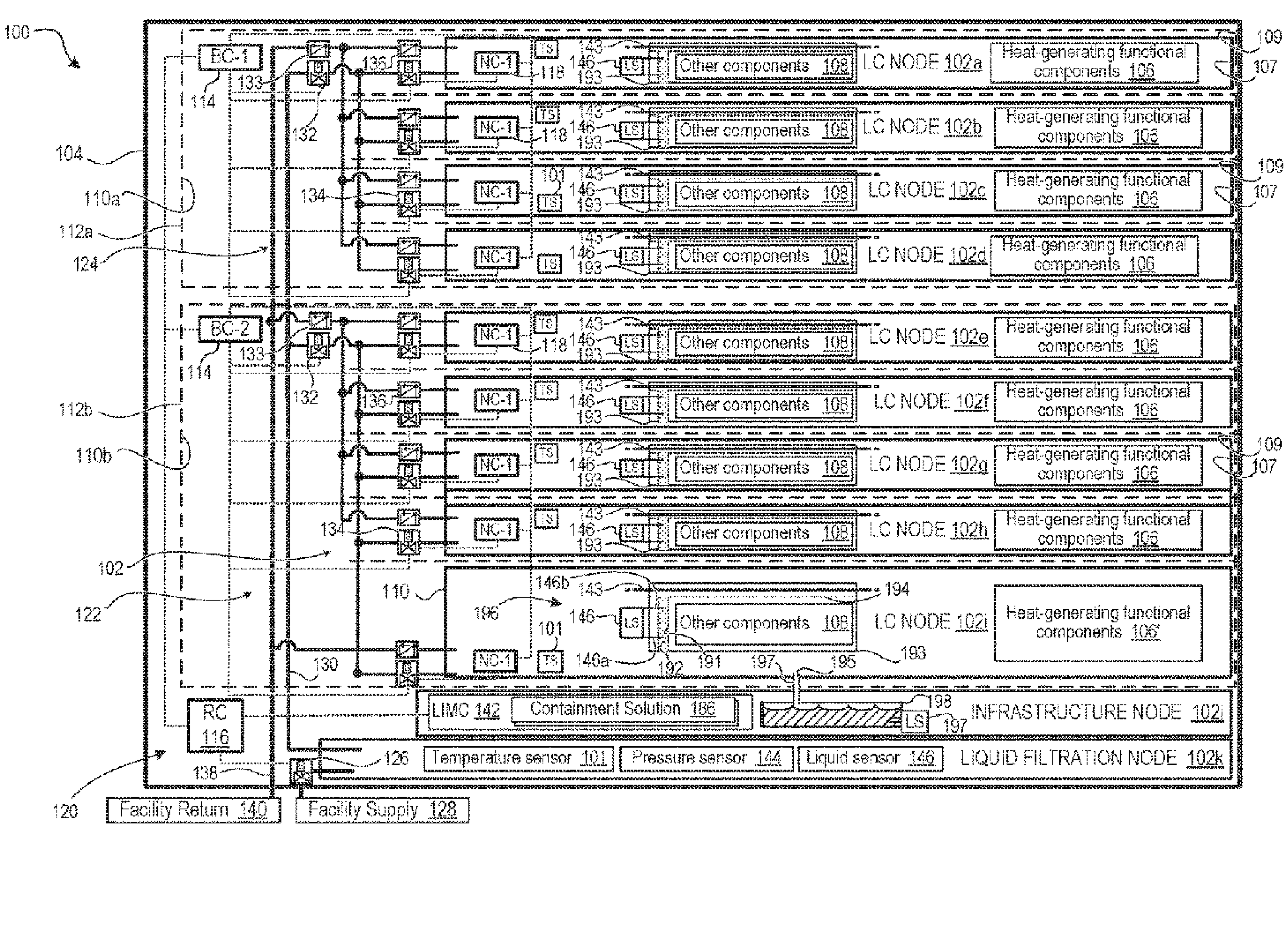
(57) **ABSTRACT**

A method of assembling a direct-contact, liquid-cooled (DL) Rack Information Handling System (RIHS) includes inserting a leak containment barrier in a node enclosure provisioned with heat-generating functional components. The method also includes attaching a system of conduits supplying cooling liquid through the node enclosure and including a supply conduit extending from a node inlet coupling and a return conduit terminating in a node outlet coupling. A trough of the leak containment barrier underlays a portion of the system of conduits of an LC node and forms a drain path to a drain port of the node enclosure. The method further includes mounting the LC node insertably received in one node-receiving slot having a rear section configured for blind mating of the node inlet and outlet ports to a node-receiving liquid inlet port and a node-receiving liquid outlet port positioned to be inwardly facing to the couplings of the LC node.

10 Claims, 15 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/270,563, filed on Dec. 21, 2015, provisional application No. 62/270,575, filed on Dec. 21, 2015.

(52) **U.S. Cl.**
CPC ***H05K 7/20772*** (2013.01); ***H05K 7/20781*** (2013.01); *G06F 1/20* (2013.01)

(58) **Field of Classification Search**
CPC H05K 7/20772; H05K 7/20818; H05K 7/20827; H05K 7/20327; H05K 7/20272; H05K 7/20763; H05K 7/20627; F25B 41/04; F28F 3/12; F28F 9/26; F28F 13/05; F28F 13/06; F28F 27/02; F28F 27/00; F28F 1/00
See application file for complete search history.

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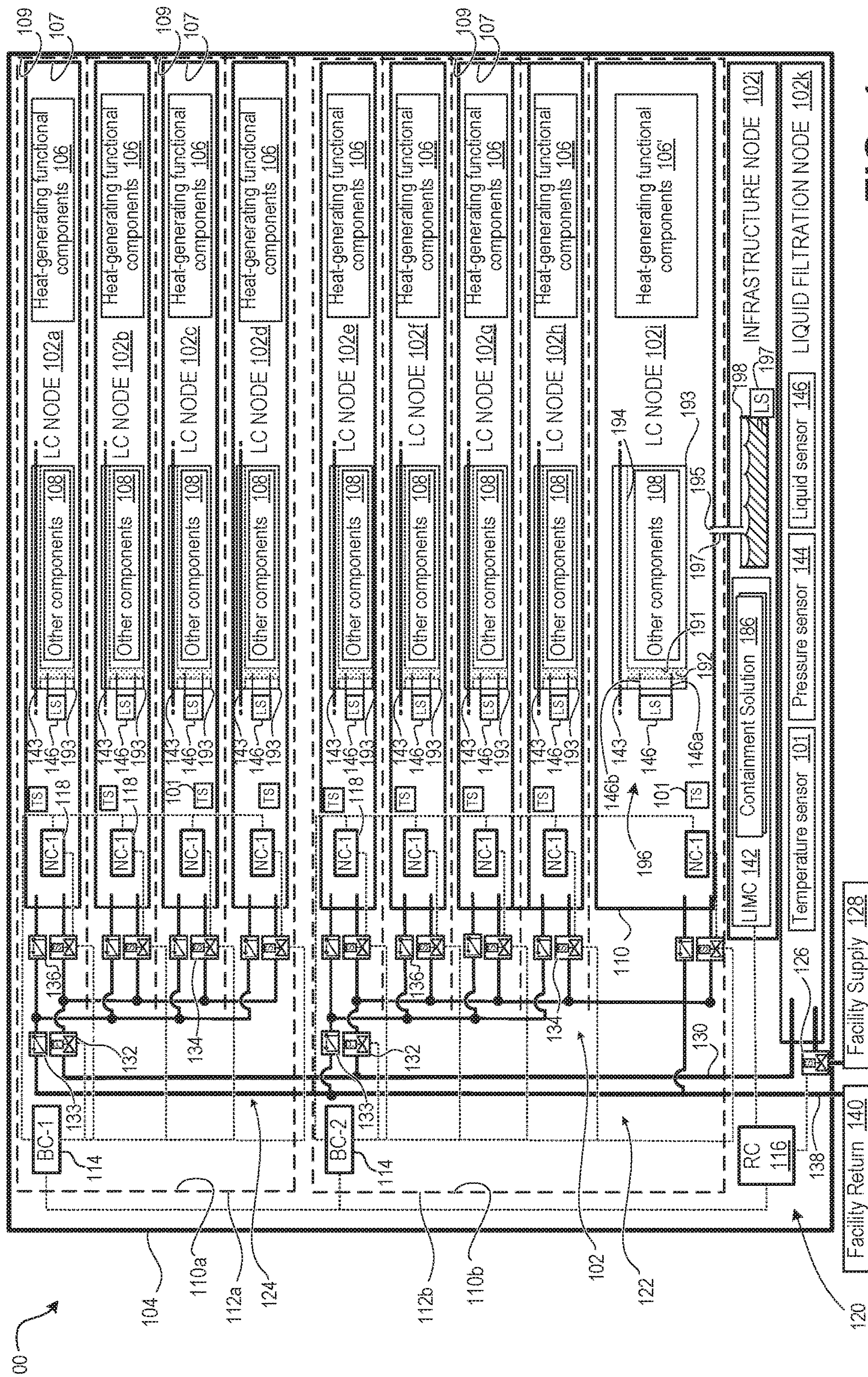
Heat-generating functional components 106
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LC NODE 102b
LC NODE 102c
LC NODE 102d
LC NODE 102e
LC NODE 102f
LC NODE 102g
LC NODE 102h
LC NODE 102i
INFRASTRUCTURE NODE 102j
LIQUID FILTRATION NODE 102k
Other components 108
LS
TS
NC-1
BC-1
BC-2
RC 116
LIMC 142
Containment Solution 186
Temperature sensor 101
Pressure sensor 144
Liquid sensor 146
Facility Supply 128
Facility Return 140
100
101
102
104
107
109
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110a
110b
112a
112b
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118
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FIG. 1

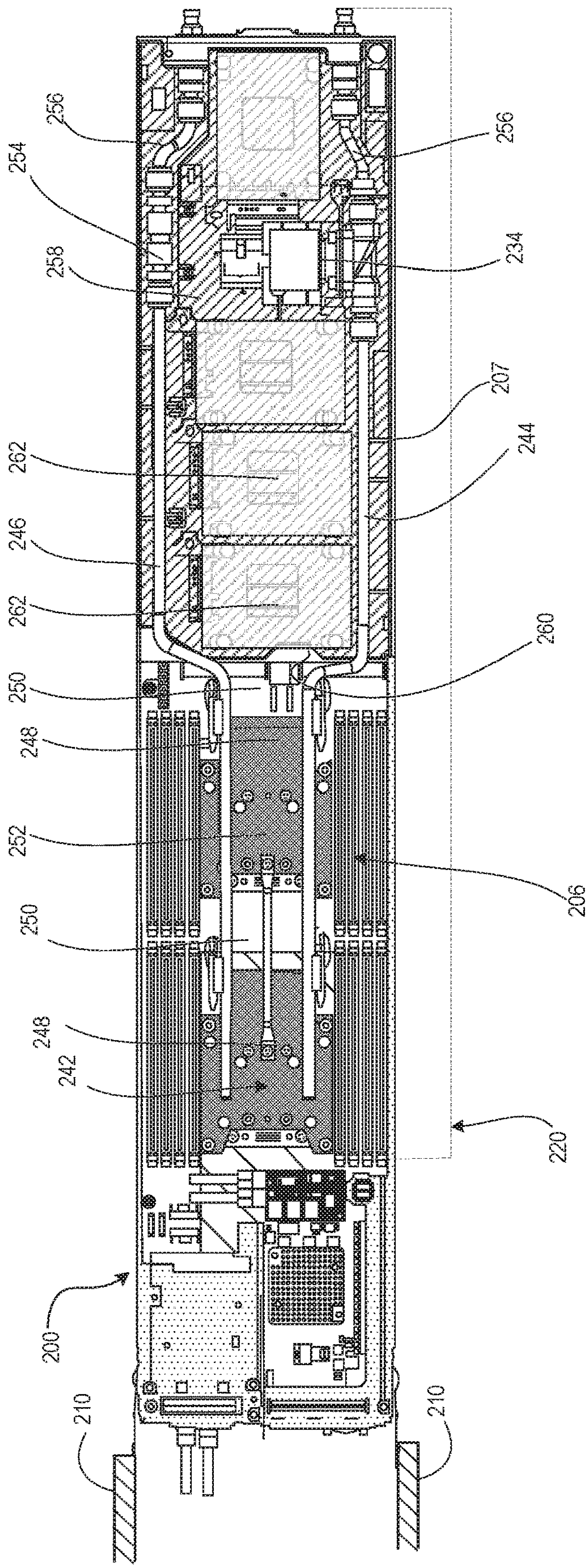
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FIG. 2

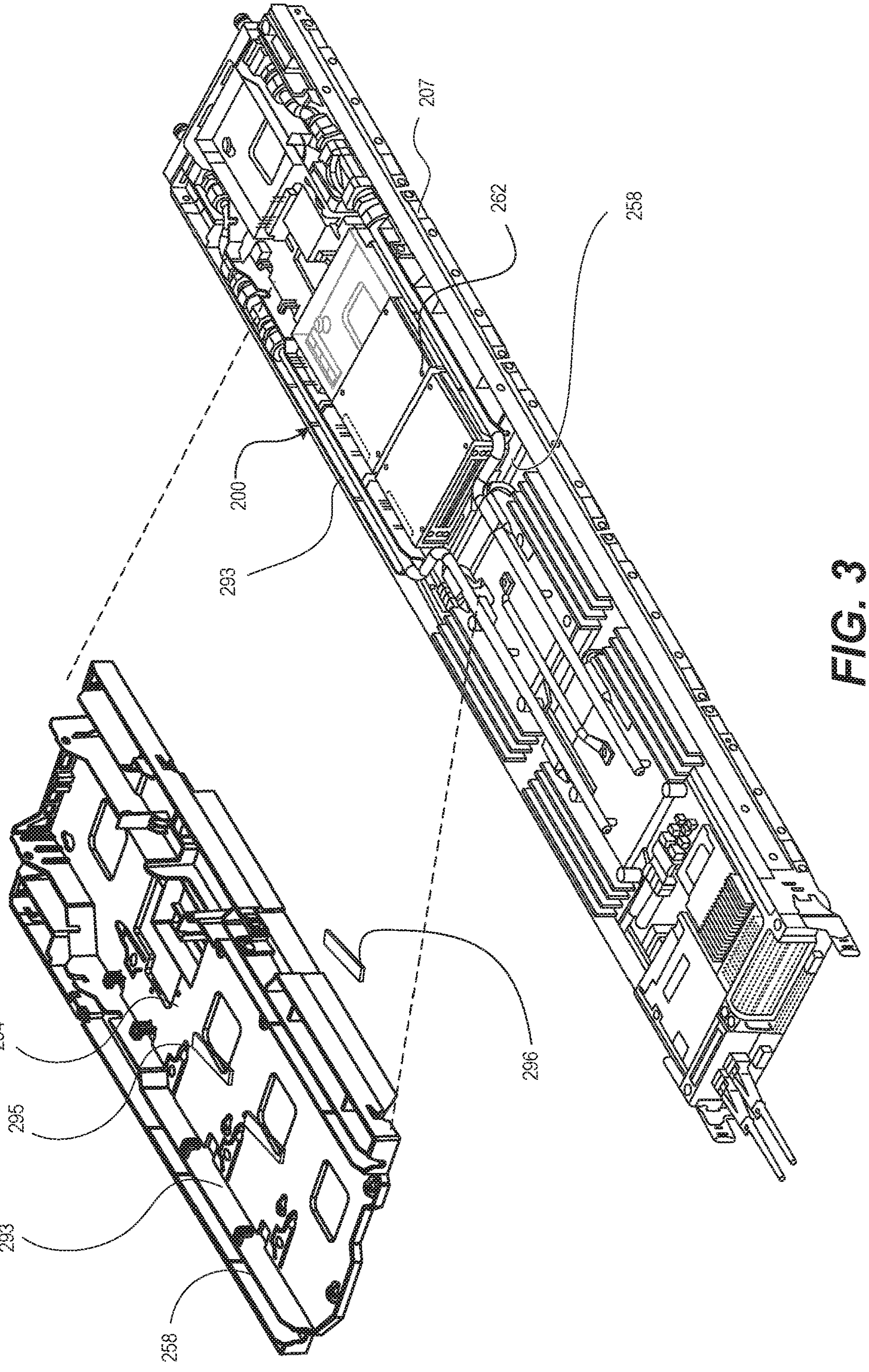
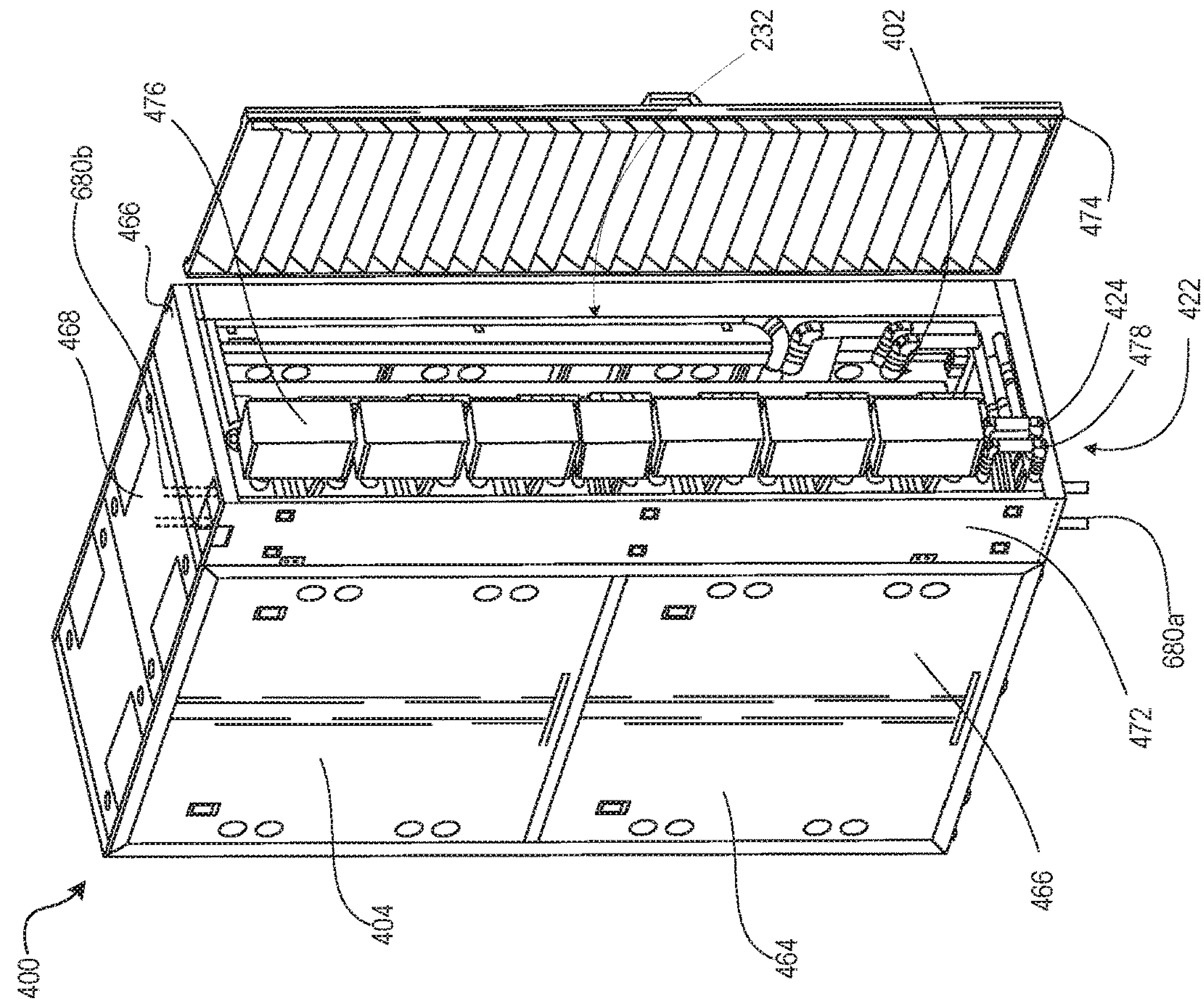


FIG. 3



232
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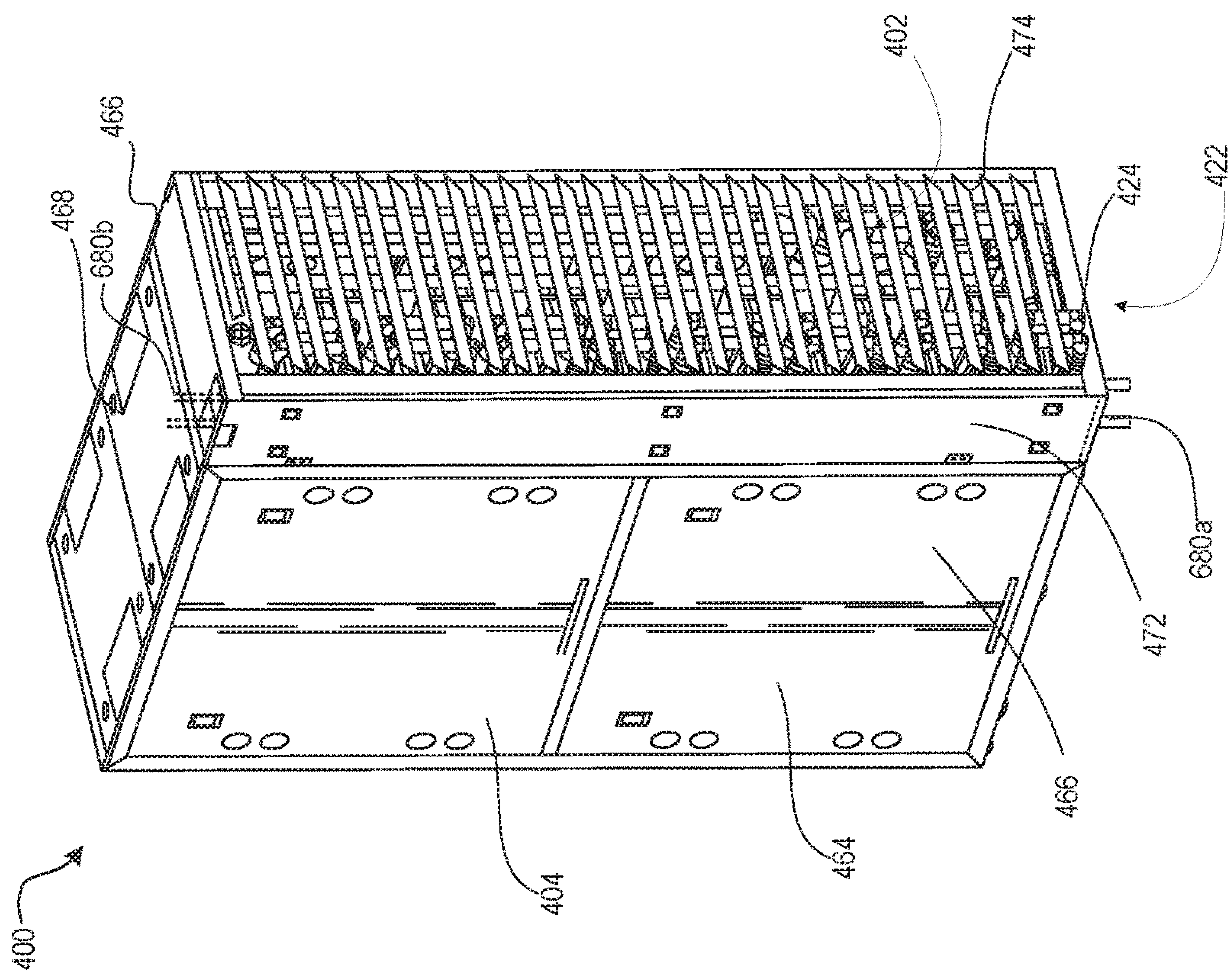
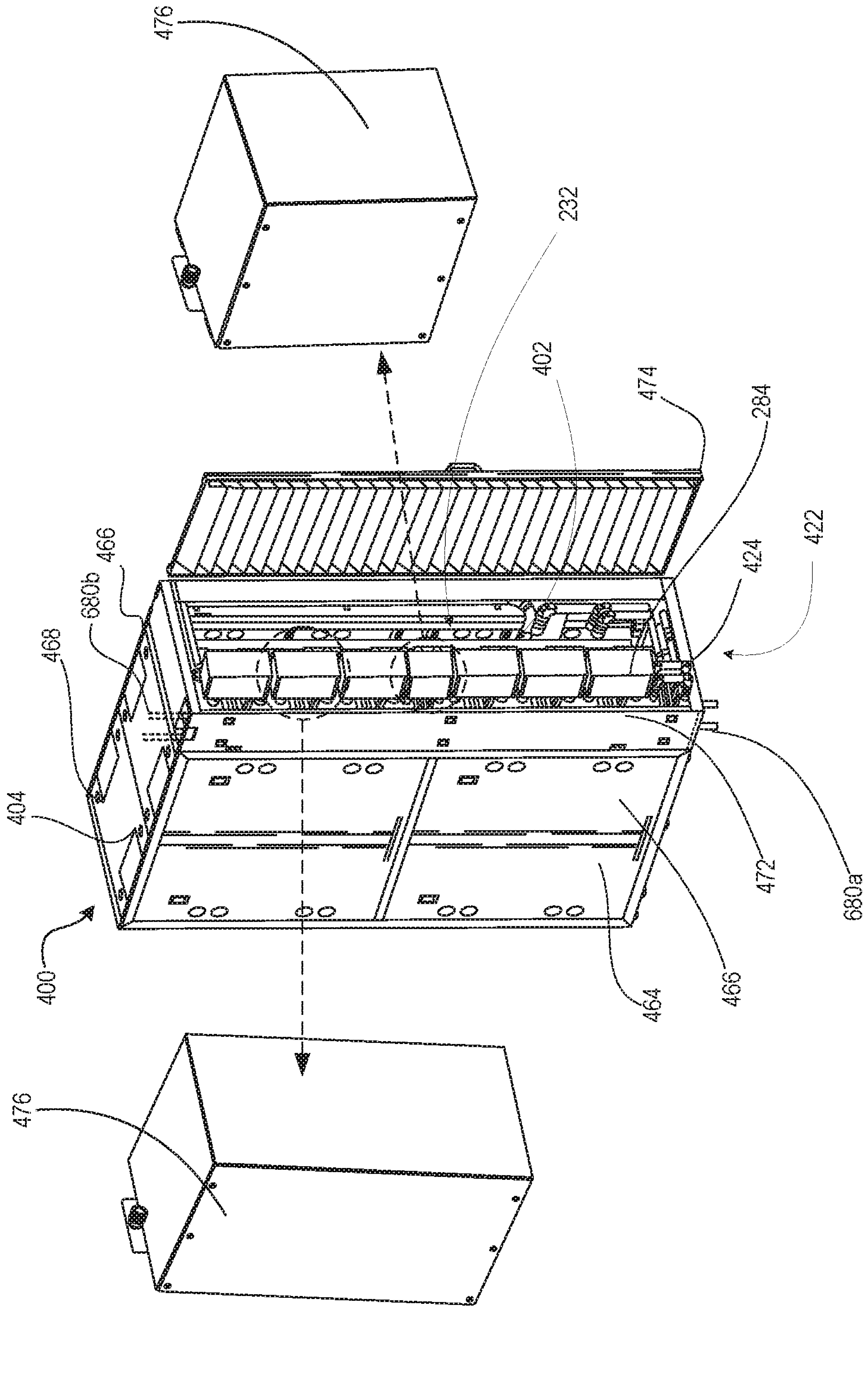
476
680b
466
468
474
424
478
422
680a
472
466
404
464
400

FIG. 5



466
468
680b
402
474
424
422
680a
472
466
464
404
400

FIG. 4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424
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404
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680a
476

FIG. 6

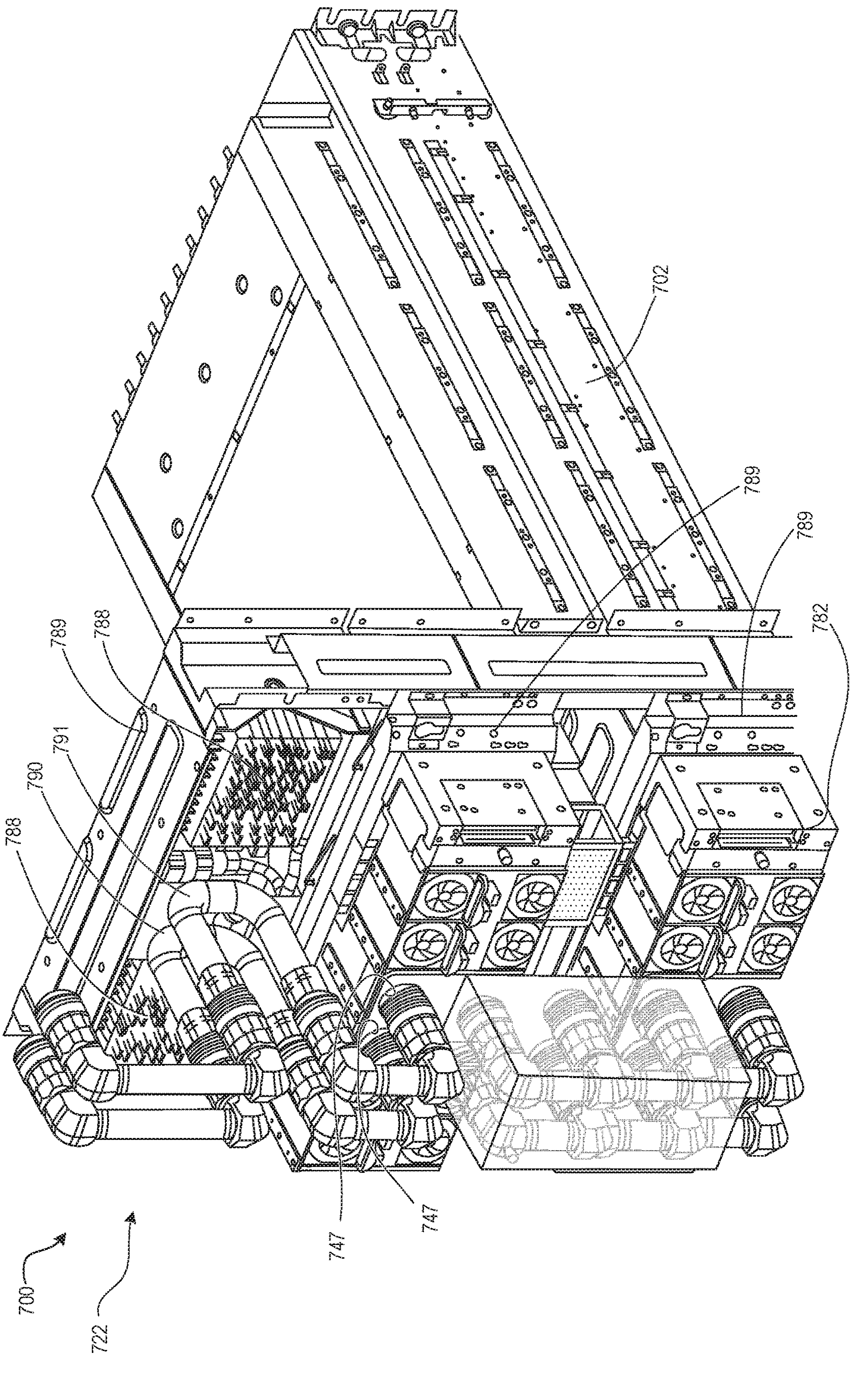
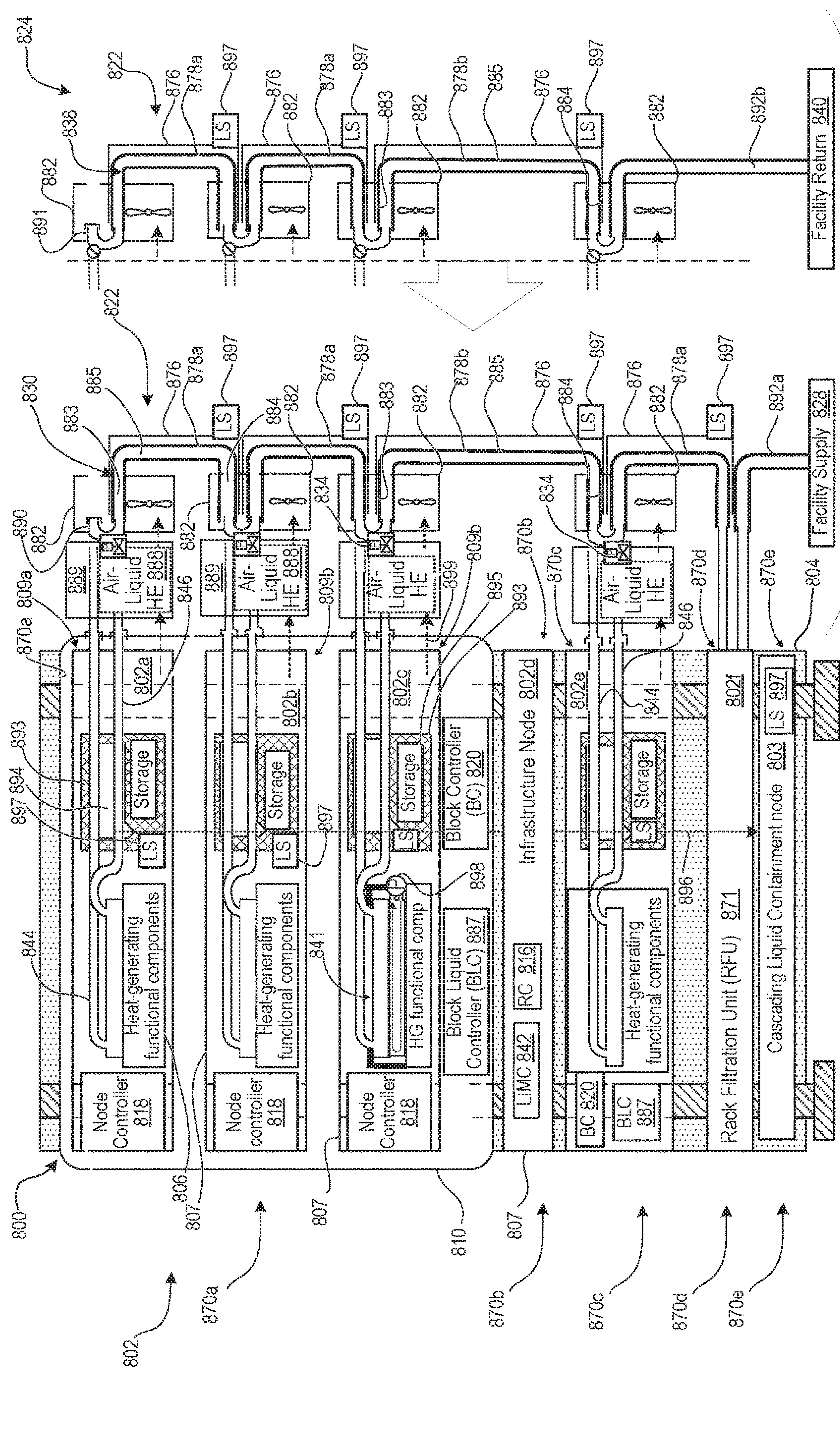


FIG. 7


824
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882
891
883
878b
885
884
892b
Facility Return 840
830
890
889
Air-Liquid HE 888
Air-Liquid HE
834
846
809a
809b
870a
870b
870c
870d
870e
804
892a
Facility Supply 828
802a
802b
802c
802d
802e
802f
893
894
897
Storage
LS
899
895
Block Controller (BC) 820
Infrastructure Node 802d
844
896
898
841
Heat-generating functional components
HG functional comp
Block Liquid Controller (BLC) 887
RC 816
LIMC 842
Node Controller 818
BC 820
BLC 887
Rack Filtration Unit (RFU) 871
Cascading Liquid Containment node 803
LS 897
800
806
807
810
802

FIG. 8

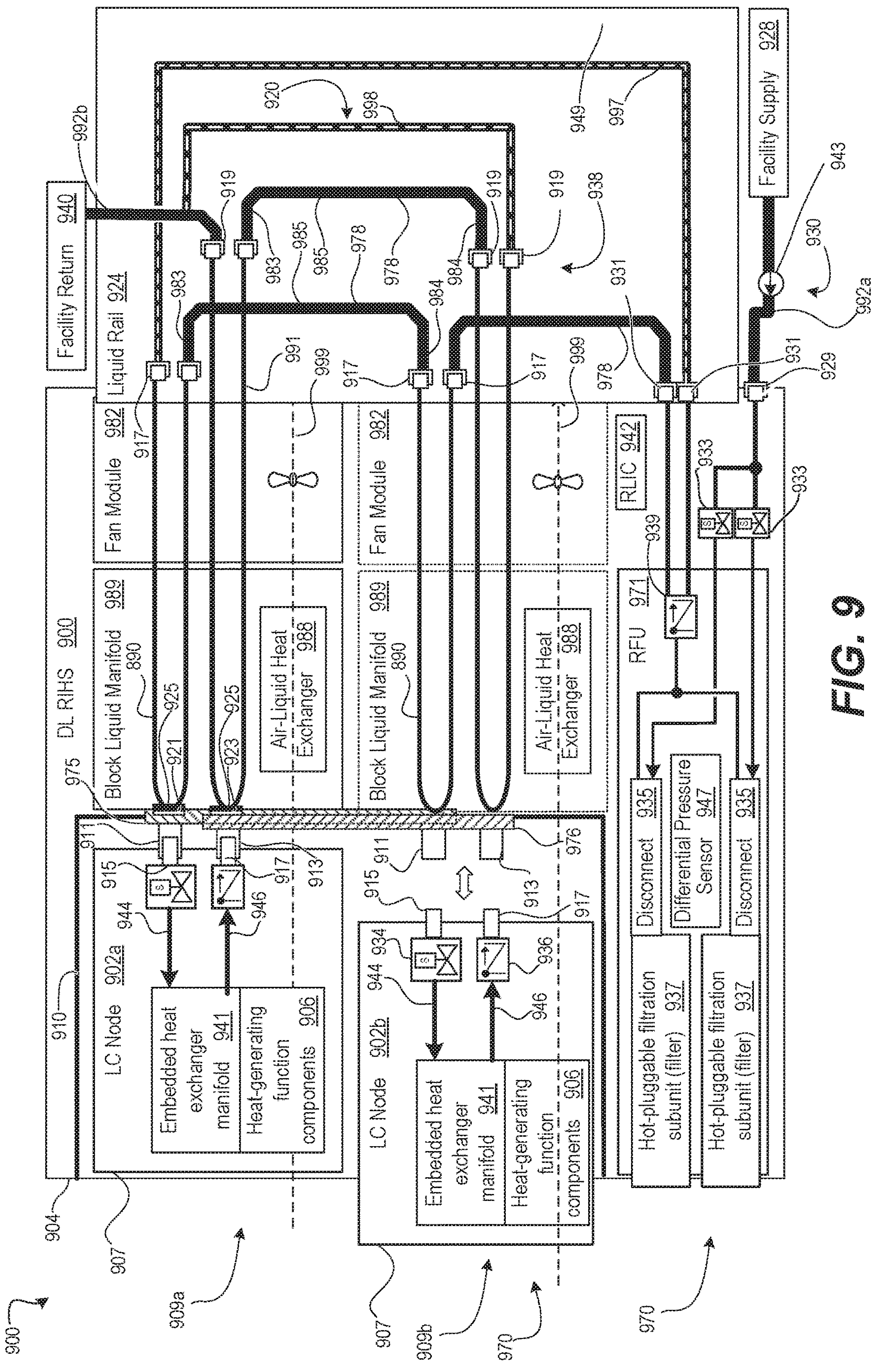
Facility Return 940
Liquid Rail 924
Facility Supply 928
DL RIHS 900
Block Liquid Manifold 989
Air-Liquid Heat Exchanger 988
Fan Module 982
RLIC 942
RFU 971
LC Node 902a
LC Node 902b
Embedded heat exchanger manifold 941
Heat-generating function components 906
Disconnect 935
Differential Pressure Sensor 947
Hot-pluggable filtration subunit (filter) 937

FIG. 9

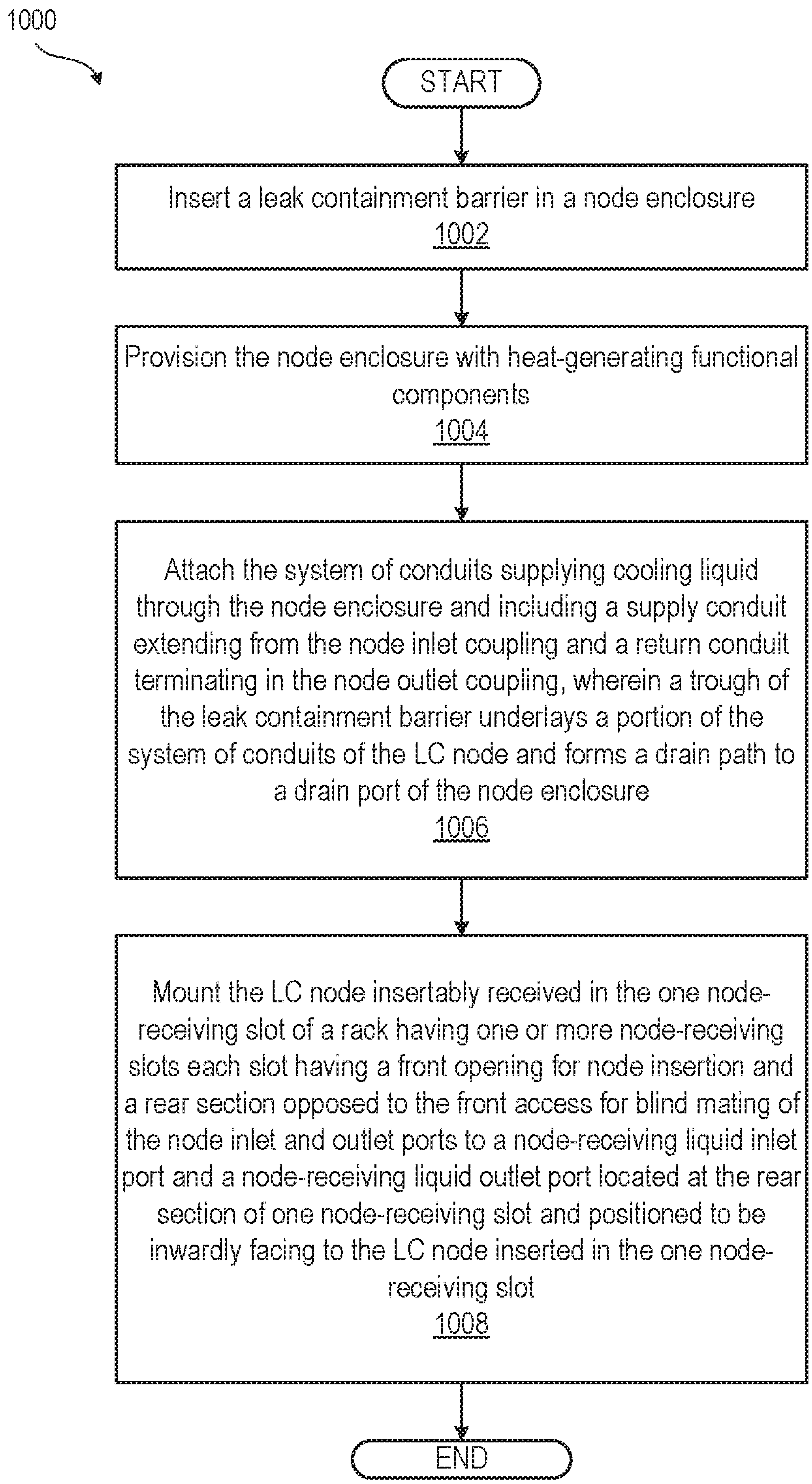
1000
START
Insert a leak containment barrier in a node enclosure
1002
Provision the node enclosure with heat-generating functional components
1004
Attach the system of conduits supplying cooling liquid through the node enclosure and including a supply conduit extending from the node inlet coupling and a return conduit terminating in the node outlet coupling, wherein a trough of the leak containment barrier underlays a portion of the system of conduits of the LC node and forms a drain path to a drain port of the node enclosure
1006
Mount the LC node insertably received in the one node-receiving slot of a rack having one or more node-receiving slots each slot having a front opening for node insertion and a rear section opposed to the front access for blind mating of the node inlet and outlet ports to a node-receiving liquid inlet port and a node-receiving liquid outlet port located at the rear section of one node-receiving slot and positioned to be inwardly facing to the LC node inserted in the one node-receiving slot
1008
END

FIG. 10

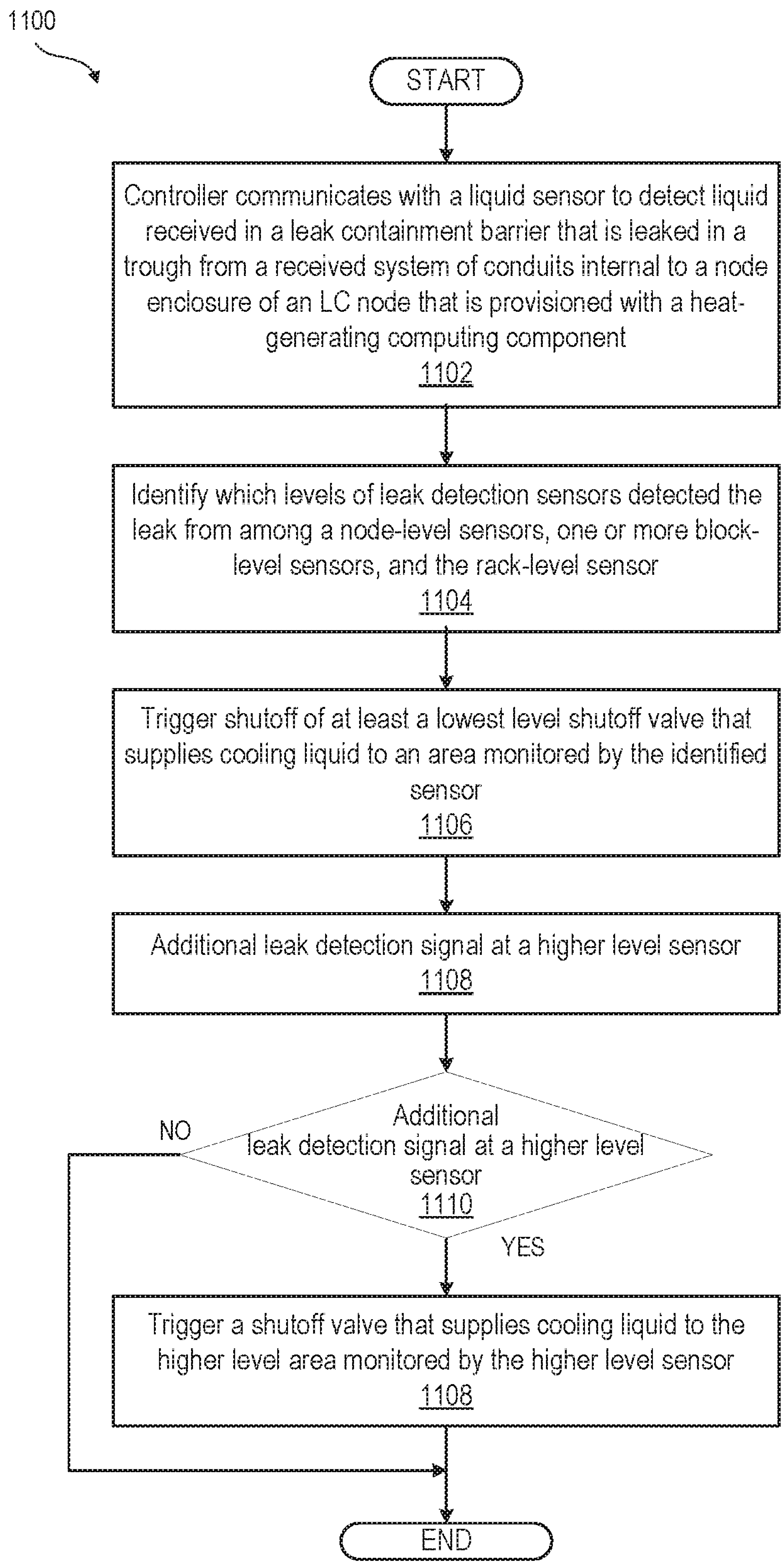
1100
START
Controller communicates with a liquid sensor to detect liquid received in a leak containment barrier that is leaked in a trough from a received system of conduits internal to a node enclosure of an LC node that is provisioned with a heat-generating computing component
1102
Identify which levels of leak detection sensors detected the leak from among a node-level sensors, one or more block-level sensors, and the rack-level sensor
1104
Trigger shutoff of at least a lowest level shutoff valve that supplies cooling liquid to an area monitored by the identified sensor
1106
Additional leak detection signal at a higher level sensor
1108
Additional leak detection signal at a higher level sensor
1110
NO
YES
Trigger a shutoff valve that supplies cooling liquid to the higher level area monitored by the higher level sensor
1108
END

FIG. 11

1200

Layer	Sensor Description	Description
Server	LCABLE_DETECT_N	The leak detect cable is present / connected
	LEAK_DETECT	Leak detect currently detecting the sensor is wet
	LEAK_DETECT_LATCHED	LEAK_DETECT was 1 at some point and latched
	SOLENOID_OPEN	Indicates the current state of the flow-control valve
Block	Block Leak Cable Detect	The leak detect cable is present / connected
	Block Leak Detect	Leak detect currently detecting the sensor is wet
	Block Leak Detect latched	LEAK_DETECT was 1 at some point and latched
	Rack Leak Cable Detect	The leak detect cable is present / connected
	Rack Leak Detect	Leak detect currently detecting the sensor is wet
	Rack Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Inlet Liquid Temperature	Temperature of incoming liquid coolant into block
	Return Liquid Temperature	Temperature of outgoing liquid coolant from block
	Block Flow rate	liquid coolant flow rate incoming into block
Rack	RFU Leak Cable Detect	The leak detect cable is present / connected
	RFU Leak Detect	Leak detect currently detecting the sensor is wet
	RFU Leak Detect latched	LEAK_DETECT was 1 at some point and latched
	Supply Leak Cable Detect	The leak detect cable is present / connected
	Supply Leak Detect	Leak detect currently detecting the sensor is wet
	Supply Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Return Leak Cable Detect	The leak detect cable is present / connected
	Return Leak Detect	Leak detect currently detecting the sensor is wet
	Return Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Inlet Liquid Temperature	Temperature of incoming liquid coolant into rack
	Return Liquid Temperature	Temperature of outgoing liquid coolant from rack
	Filter Tray 1 Flow rate	liquid coolant flow rate outbound filter tray 1
	Filter Tray 2 Flow rate	liquid coolant flow rate outbound filter tray 2
Filter Differential Pressure	differential pressure across the combined filtration trays	

FIG. 12

1300

Scenario #	Local Sensors	Status	Possible Causes	Behavior	Reporting	Impact
1	RFU Leak Sensor Presence	Present	N/A	Normal Operation	Normal Operation	None
	RFU Leak Detection	Normal				
	Filter Drawer 1 Flowrate	Normal				
	Filter Drawer 2 Flowrate	Normal				
	Filter System Differential Pressure	Low-Normal				
	Flow Valve Position	Open				
2	RFU Leak Sensor Presence	Not Present	Sensor Wire Not Connected	Do Nothing	Alert: LIMB → MC	None
	RFU Leak Detection	Not Present				
	Filter Drawer 1 Flowrate	Normal				
	Filter Drawer 2 Flowrate	Normal				
	Filter System Differential Pressure	Low-Normal				
	Flow Valve Position	Open				
3	RFU Leak Sensor Presence	Present	Leak within RFU	Close rack supply valve, graceful shut down all sleds within rack	Alert: LIMB → MC	Whole rack loses water supply – graceful shutdown all rack servers
	RFU Leak Detection	Failed				
	Filter Drawer 1 Flowrate	Normal				
	Filter Drawer 2 Flowrate	Normal				
	Filter System Differential Pressure	Low-Normal				
	Flow Valve Position	Fail to close				
4	RFU Leak Sensor Presence	Present	RFU Flow Valve Stuck	Gracefully shut down all sleds within rack	Alert: LIMB → MC	Graceful shutdown all rack servers
	RFU Leak Detection	Failed				
	Filter Drawer	Normal				

FIG. 13

1400

Scenario #	Local Sensors	Status	Possible Causes	Behavior	Reporting	Impact
1	Block Leak Sensor Presence	Present	N/A	Normal Operation	Normal Operation	None
	Block Leak Detection	Normal				
	Rack Leak Sensor Presence	Present				
	Rack Leak Detection	Normal				
	Flow Valve Position	Open – XX%				
2	Block Leak Sensor Presence	**Not Present**	Sensor Wire Not Connected	Do Nothing	Alert: BLCB → MC	None
	Block Leak Detection	**Not Present**				
	Rack Leak Sensor Presence	Normal				
	Rack Leak Detection	Normal				
	Flow Valve Position	Low-Normal				
3	Block Leak Sensor Presence	Present	Water Leak within Block assembly	Block self protect: close block valve, initiate shut down on sleds	Alert: BLCB → MC	All block servers graceful shut down
	Block Leak Detection	**Failed**				
	Rack Leak Sensor Presence	Present				
	Rack Leak Detection	Normal				
	Flow Valve Position	Open – XX%				
4	Block Leak Sensor Presence	Present	Proportional Valve Stuck	Power down block sleds Rack RFU valve close	Alert: BLCB → MC	Whole rack loses water supply graceful shutdown all rack servers
	Block Leak Detection	**Failed**				
	Rack Leak Sensor Presence	Present				
	Rack Leak Detection	Normal				
	Flow Valve Position	**Fail to close**				

FIG. 14

1500

Scenario #	Local Sensors	Status	Possible Causes	Behavior	Reporting	Impact
1	Leak Sensor Presence	Present	N/A	Normal Operation	Normal Operation	None
	Leak Detection	Normal				
	Flow Valve Position	Open				
2	Leak Sensor Presence	**Not present**	Sensor wire not connecte d	Do nothing	Alert NPDB → BC → MC	None
	Leak Detection	**Not present**				
	Flow Valve Position	Open				
3	Leak Sensor Presence	Present	Water leak within sled	Sled self protect: power down and close valve	Alert NPDB → BC → MC	Single server shutdown
	Leak Detection	**Failed**				
	Flow Valve Position	Open				
4	Leak Sensor Presence	Present	Solenoid valve stuck	Sled power down, report to BC, block valve close	Alert NPDB → BC → MC	All block servers graceful shutdown (12)
	Leak Detection	**Failed**				
	Flow Valve Position	**Failed to close**				

FIG. 15

1600

Layer	Sensor Description	Description
Server	LCABLE_DETECT_N	The leak detect cable is present / connected
	LEAK_DETECT	Leak detect currently detecting the sensor is wet
	LEAK_DETECT_LATCHED	LEAK_DETECT was 1 at some point and latched
	SOLENOID_OPEN	Indicates the current state of the flow-control valve
Block	Block Leak Cable Detect	The leak detect cable is present / connected
	Block Leak Detect	Leak detect currently detecting the sensor is wet
	Block Leak Detect latched	LEAK_DETECT was 1 at some point and latched
	Rack Leak Cable Detect	The leak detect cable is present / connected
	Rack Leak Detect	Leak detect currently detecting the sensor is wet
	Rack Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Inlet Liquid Temperature	Temperature of incoming liquid coolant into block
	Return Liquid Temperature	Temperature of outgoing liquid coolant from block
	Block Flow rate	liquid coolant flow rate incoming into block
Rack	RFU Leak Cable Detect	The leak detect cable is present / connected
	RFU Leak Detect	Leak detect currently detecting the sensor is wet
	RFU Leak Detect latched	LEAK_DETECT was 1 at some point and latched
	Supply Leak Cable Detect	The leak detect cable is present / connected
	Supply Leak Detect	Leak detect currently detecting the sensor is wet
	Supply Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Return Leak Cable Detect	The leak detect cable is present / connected
	Return Leak Detect	Leak detect currently detecting the sensor is wet
	Return Leak Detect Latched	LEAK_DETECT was 1 at some point and latched
	Inlet Liquid Temperature	Temperature of incoming liquid coolant into rack
	Return Liquid Temperature	Temperature of outgoing liquid coolant from rack
	Filter Tray 1 Flow rate	liquid coolant flow rate outbound filter tray 1
	Filter Tray 2 Flow rate	liquid coolant flow rate outbound filter tray 2
	Filter Differential Pressure	differential pressure across the combined filtration trays

FIG. 16

LIQUID COOLED RACK INFORMATION HANDLING SYSTEM HAVING STORAGE DRIVE CARRIER FOR LEAK CONTAINMENT AND VIBRATION MITIGATION

PRIORITY

This application is a divisional of U.S. application Ser. No. 15/049,074, filed Feb. 20, 2016, which claims priority from each of the following provisional patent applications, with relevant content of each listed provisional application incorporated herein by reference: Provisional Application Ser. No. 62/270,563, with filing date Dec. 21, 2015; and Provisional Application Ser. No. 62/270,575, with filing date Dec. 21, 2015.

BACKGROUND

1. Technical Field

The present disclosure generally relates to information handling systems (IHS), and more particular to a direct-interface liquid cooled (DL) rack-configured HIS (RIHS), having a liquid cooling subsystem and liquid-cooled nodes. Still more particularly, the disclosure is related to mitigating risk to computing components from cooling liquid leaks within the RIHS.

2. Description of the Related Art

As the value and use of information continue to increase, individuals and businesses seek additional ways to process and store information. One option available to users is Information Handling Systems (IHSs). An IHS generally processes, compiles, stores, and/or communicates information or data for business, personal, or other purposes, thereby allowing users to take advantage of the value of the information. Because technology and information handling needs and requirements vary between different users or applications, IHSs may also vary regarding what information is handled, how the information is handled, how much information is processed, stored, or communicated, and how quickly and efficiently the information may be processed, stored, or communicated. The variations in IHSs allow for IHSs to be general or configured for a specific user or specific use such as financial transaction processing, airline reservations, enterprise data storage, or global communications. In addition, IHSs may include a variety of hardware and software components that may be configured to process, store, and communicate information and may include one or more computer systems, data storage systems, and networking systems.

For implementations requiring a large amount of processing capability, a rack-configured (or rack) IHS (RIHS) can be provided. The RIHS includes a physical rack, within which is inserted a plurality of functional nodes, such as server (or processing) nodes/modules, storage nodes, and power supply nodes. These nodes, and particularly the server nodes, typically include processors and other functional components that dissipate heat when operating and/or when connected to a power supply. Efficient removal of the heat being generated by these components is required to maintain the operational integrity of the RIHS. Traditional heat removal systems include use of air movers, such as fans, to convectionally transfer the heat from inside of the RIHS to outside the RIHS. More recently, some RIHS have been designed to enable submersion of the server modules and/or the heat generating components in a tank of cooling liquid to effect cooling via absorption of the heat by the surrounding immersion liquid.

The amount of processing capacity and storage capacity per node and/or per rack continues to increase, providing greater heat dissipation per node and requiring more directed cooling solutions. Thus, there is a continuing need for further innovations to provide directed cooling for the individual heat generating components, both at the individual node level, as well as at the larger rack level. When designing the cooling subsystem, consideration must also be given to the different form factors of IT nodes and rack heights of the RIHS, and the ability to effectively control cooling discretely (at device or node level) and generally across the overall RIHS.

As liquid cooling improves in efficiencies and performance, data center solutions continue to focus on implementing liquid cooling at the rack level. Recently, localized liquid solutions (CPU/GPU cold plates) have been successful in removing most of the heat from these components within a server and into the facility cooling loop through direct fluid-to-fluid heat exchangers (server cooling loop to facility cooling loop) within the rack. However, when liquid is introduced into an electronic enclosure, there is potential for leaks, which can cause catastrophic system failure. Within the system enclosure, locations exist where an electronic short will create an exothermal reaction that can cause permanent damage to the system.

BRIEF SUMMARY

The illustrative embodiments of the present disclosure provides a Direct-Interface Liquid-Cooled (DL) Rack Information Handling System (RIHS), a direct-interface liquid cooling subsystem, and a method for modularly providing liquid cooling to information technology (IT) nodes within a RIHS, where the nodes are liquid cooled (LC) nodes that contain heat-generating functional components that require protection from any liquid that leaks from DL subsystem.

According to one aspect, a DL RIHS includes a rack having chassis-receiving bays. The DL RIHS includes at least one LC node having a chassis received in a respective chassis-receiving bay of the rack. The chassis contains heat-generating functional components. The LC node is configured with a system of conduits to receive direct injection of cooling liquid to regulate the ambient temperature of the node. The direct injection provides cooling to the functional components inside the node by removing heat generated by the heat-generating functional components. The chassis includes a leak containment barrier configured with a trough that underlays a portion of the system of conduits of the LC node. The trough forms a drain path to a drain port of the chassis. In one or more embodiments, the storage drive carrier comprises vibration absorbing material that mitigates vibrations of a storage drive placed in the storage drive carrier.

According to one aspect, an LC node of an RIHS includes a chassis configured to be received in chassis-receiving bay of a rack. At least one heat-generating functional component that generates heat internal to the chassis requires cooling. A system of conduits has an inlet port and an outlet port for connecting to a cooling liquid supply to receive direct intake/flow of cooling liquid. The cooling liquid regulates the ambient temperature of the LC node by absorbing and transferring heat from within the node via the cooling liquid. A leak containment barrier is configured with a trough that underlays a portion of the system of conduits of the LC node. The trough forms a drain path to a drain port of the chassis.

According to one aspect, the present disclosure provides a method of assembling a DL RIHS. In one or more embodiments, the method includes inserting a leak containment barrier in a node enclosure. The method includes provisioning the node enclosure with heat-generating functional components. The method includes attaching the system of conduits supplying cooling liquid through the node enclosure. The system of conduits includes a supply conduit extending from the node inlet coupling and a return conduit terminating in the node outlet coupling. A trough of the leak containment barrier underlays a portion of the system of conduits of the LC node and forms a drain path to a drain port of the node enclosure. The method includes mounting the LC node insertably received in the one node-receiving slot of a rack having one or more node-receiving slots. Each slot has a front opening for node insertion and a rear section opposed to the front access. For blind mating of the node inlet and outlet ports, a node-receiving liquid inlet port and a node-receiving liquid outlet port are located at the rear section of one node-receiving slot. The node-receiving liquid inlet and outlet ports are positioned to be inwardly facing to the LC node inserted in the one node-receiving slot.

According to one aspect, the present disclosure provides a method of containing leaks in a DL RIHS. In one or more embodiments, the method includes a controller communicating with a liquid sensor to detect liquid received in a leak containment barrier. The detected liquid is leaked in a trough from a received system of conduits internal to a node enclosure of a LC node that is provisioned with a heat-generating computing component. The method includes interrupting the supply flow of cooling liquid to the LC node by causing a shutoff valve to close.

The above presents a general summary of several aspects of the disclosure in order to provide a basic understanding of at least some aspects of the disclosure. The above summary contains simplifications, generalizations and omissions of detail and is not intended as a comprehensive description of the claimed subject matter but, rather, is intended to provide a brief overview of some of the functionality associated therewith. The summary is not intended to delineate the scope of the claims, and the summary merely presents some concepts of the disclosure in a general form as a prelude to the more detailed description that follows. Other systems, methods, functionality, features and advantages of the claimed subject matter will be or will become apparent to one with skill in the art upon examination of the following figures and detailed written description.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the illustrative embodiments can be read in conjunction with the accompanying figures. It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements. Embodiments incorporating teachings of the present disclosure are shown and described with respect to the figures presented herein, in which:

FIG. **1** illustrates a side perspective view of an internal layout/configuration of an example Direct-Interface Liquid-Cooled (DL) RIHS, according to one or more embodiments;

FIG. **2** illustrates a top view of an example LC node configured with a liquid cooling subsystem that includes a liquid-to-liquid manifold and cooling pipes for conductively cooling internal functional components, according to one or more embodiments;

FIG. **3** illustrates a front perspective view of the example LC node of FIG. **2** with a detailed view of a leak containment barrier, according to one or more embodiments;

FIG. **4** illustrates a rear perspective view of an example DL RIHS with a louvered rear door in a closed position over uncovered MLD conduits, according to one or more embodiments;

FIG. **5** illustrates a rear perspective view of an example DL RIHS with a louvered rear door in an open position, according to one or more embodiments;

FIG. **6** illustrates the rear perspective view of FIGS. **4**-**5** with the pipe covers removed to expose modular liquid distribution (MLD) conduits, according to one or more embodiments;

FIG. **7** illustrates a perspective view of a portion of a DL RIHS depicting example nodes, block radiators with Air-Liquid heat exchangers, and MLD conduits, according to one or more embodiments;

FIG. **8** illustrates a detailed block diagram of a DL RIHS configured with LC nodes arranged in blocks and which are cooled in part by a liquid cooling system having a rail comprised of MLD conduits, and in part by a subsystem of air-liquid heat exchangers, according to multiple embodiments;

FIG. **9** illustrates an expanded, more detailed view of the liquid interconnection between the node level heat exchange manifold, the block liquid manifold containing the air-liquid heat exchanger, and example MLDs of the liquid rail, according to multiple embodiments;

FIG. **10** illustrates a flow diagram of a method of assembling a DL RIHS, according to one or more embodiments;

FIG. **11** illustrates a flow diagram of a method of containing leaks in a DL RIHS, according to one or more embodiments;

FIG. **12** illustrates a table data structure of a listing of receiving node (server), block and rack-level sensor signals, according to one or more embodiments;

FIG. **13** illustrates a table data structure of a listing sensor signals associated with rack-level scenarios and rack-level leak containment solutions, according to one or more embodiments;

FIG. **14** illustrates a table data structure of a listing sensor signals with block-level scenarios and block-level leak containment solutions, according to one or more embodiments;

FIG. **15** illustrates a table data structure of a listing of sensor signals with node-level scenarios and node-level leak containment solutions, according to one or more embodiments; and

FIG. **16** illustrates a table data structure of a listing of sensor signals associated with sensors.

DETAILED DESCRIPTION

The present disclosure generally provides a Direct-Interface Liquid-Cooled (DL) Rack Information Handling System (RIHS) providing liquid cooled (LC) information technology (IT) nodes containing heat-generating functional components and which are cooled at least in part by a liquid cooling subsystem. The RIHS includes a rack configured with chassis-receiving bays in which is received a respective chassis of one of the LC nodes. Each LC node is configured with a system of conduits to receive direct intake/flow of cooling liquid to regulate the ambient temperature of the node. Additionally, each LC node, configured with a system of conduits, provides cooling to the components inside the node by conductively absorbing, via the cooling liquid, heat generated by the heat-generating functional components. The absorbed heat is removed (or transferred away) from within the node to outside of the node and/or the RIHS.

The chassis has a leak containment barrier configured with a trough that underlays a portion of the system of conduits of the LC node and that forms a drain path to a drain port of the chassis. Based on portions of the RIHS that can be exposed to the leak, a Liquid Infrastructure Management Controller (LINC) implements a leak detection solution to avoid or mitigate damage to computing components.

In the following detailed description of exemplary embodiments of the disclosure, specific exemplary embodiments in which the disclosure may be practiced are described in sufficient detail to enable those skilled in the art to practice the disclosed embodiments. For example, specific details such as specific method orders, structures, elements, and connections have been presented herein. However, it is to be understood that the specific details presented need not be utilized to practice embodiments of the present disclosure. It is also to be understood that other embodiments may be utilized and that logical, architectural, programmatic, mechanical, electrical and other changes may be made without departing from general scope of the disclosure. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims and equivalents thereof.

References within the specification to "one embodiment," "an embodiment," "embodiments", or "one or more embodiments" are intended to indicate that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. The appearance of such phrases in various places within the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Further, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not other embodiments.

It is understood that the use of specific component, device and/or parameter names and/or corresponding acronyms thereof, such as those of the executing utility, logic, and/or firmware described herein, are for example only and not meant to imply any limitations on the described embodiments. The embodiments may thus be described with different nomenclature and/or terminology utilized to describe the components, devices, parameters, methods and/or functions herein, without limitation. References to any specific protocol or proprietary name in describing one or more elements, features or concepts of the embodiments are provided solely as examples of one implementation, and such references do not limit the extension of the claimed embodiments to embodiments in which different element, feature, protocol, or concept names are utilized. Thus, each term utilized herein is to be given its broadest interpretation given the context in which that terms is utilized.

As utilized herein, the term "rack-configured" (as in RIHS) generally refers to the configuration of a large scale sever system within a physical rack having multiple chassis receiving rails for receiving specific sizes of information technology (IT) nodes, such as server modules, storage modules, and power modules. The term node generally refers to each separate unit inserted into a 1U or other height rack space within the rack. In one embodiment, operational characteristics of the various IT nodes can be collectively controlled by a single rack-level controller. However, in the illustrated embodiments, multiple nodes can be arranged into blocks, with each block having a separate block-level controller that is communicatively connected to the rack-level controller.

For purposes of this disclosure, an information handling system (defined at the individual server level) may include any instrumentality or aggregate of instrumentalities operable to compute, classify, process, transmit, receive, retrieve, originate, switch, store, display, manifest, detect, record, reproduce, handle, or utilize any form of information, intelligence, or data for business, scientific, control, or other purposes. For example, an information handling system may be a personal computer, a network storage device, or any other suitable device and may vary in size, shape, performance, functionality, and price. The information handling system may include random access memory (RAM), one or more processing resources such as a central processing unit (CPU) or hardware or software control logic, ROM, and/or other types of nonvolatile memory. Additional components of the information handling system may include one or more disk drives, one or more network ports for communication with external devices as well as various input and output (I/O) devices, such as a keyboard, a mouse, and a video display. The information handling system may also include one or more buses operable to transmit communications between the various hardware components.

As illustrated by the figures and described herein, multiple processing servers or server IHSs (referred to herein as server nodes) can be included within the single RIHS. Certain aspect of the disclosure then relate to the specific LC (sever or other) nodes and the functionality associated with these individual nodes or block-level groupings of nodes, while other aspects more generally relate to the overall DL RIHS containing all of the LC nodes.

As one design detail/aspect for the present innovation, consideration is given to the fact that extreme variations can exist in server/power/network topology configurations within an IT rack. In addition to dimension variations, the thermal requirements for heat-generating functional components for power, control, storage and server nodes can be very different between types or vary according to usage. These variations drive corresponding extreme diversity in port placement, fitting size requirements, mounting locations, and manifold capacity for a liquid cooling subsystem. Further, a chassis of each node is typically densely provisioned. Lack of space thus exists to mount a discrete water distribution manifold in high-power IT racks. The present disclosure addresses and overcomes the challenges with distributing liquid cooling fluids throughout an IT rack having nodes with a large number of variations in distribution components.

The disclosure also includes the additional consideration that in addition to cooling the primary heat generating components of the rack, such as the processor, what is needed is a way to allow for cooling of secondary equipment within the rack, as well as auxiliary components that would further support utilizing the advantages of a fluid-to-fluid heat exchanger methodology. Additionally, the present disclosure provides a modular approach to utilizing an air-to-liquid heat exchanger with quick connection and scalability to allow the solution to be scalable in both 1U and 2U increments.

FIG. **1** illustrates a side perspective view of an internal layout/configuration of an example Direct-Interface Liquid-Cooled (DL) RIHS **100** configured with a plurality of LC nodes **102**, according to one or more embodiments. For simplicity, the example DL RIHS presented in the various illustrations can be described herein as simply RIHS **100**; however, references to RIHS **100** are understood to refer to a DL RIHS, with the associated liquid cooling infrastructure and/or subsystems and supported LC nodes **102**. RIHS **100** includes rack **104**, which comprises a rack frame and side panels, creating a front-to-back cabinet within which a plurality of chassis receiving bays are vertically arranged and in which a chassis of a respective IT node **102** can be inserted. Rack **104** includes certain physical support structures (not specifically shown) that support IT gear insertion at each node location. Additional description of the structural make-up of an example rack is provided in the description of FIGS. **2-4**, which follows.

FIG. **1** depicts an illustrative example of LC nodes **102***a*-**102***j* (collectively refer to as nodes **102**), with each nodes **102***a*-**102***i* including heat-generating functional components **106**. Additionally, RIHS **100** also includes an infrastructure node **102***j* and liquid filtration node **102***k*, which do not necessarily include heat-generating functional components **106** that require liquid cooling, as the other LC nodes **102***a*-**102***i*. In the illustrative embodiments, nodes **102***a*-**102***b*, and **102***e*-**102***h* include other components **108** that are not necessarily heat generating, but which are exposed to the same ambient heat conditions as the heat generating components by virtue of their location within the node. In one embodiment, these other components **108** can be sufficiently cooled by the direct-interface liquid cooling applied to the node and/or using forced or convective air movement, as described later herein. Each node **102** is supported and protected by a respective node enclosure **107**. Nodes **102***a*-**102***d* are further received in node receiving bays **109** of a first block chassis **110***a* of a first block **112***a*. Nodes **102***e*-**102***i* are received in a second block chassis **110** of a second block **112***b*. In the illustrative embodiments, the nodes **102** are vertically arranged. In one or more alternate embodiments, at least portions of the nodes **102** (and potentially all of the nodes) may also be arranged horizontally while benefiting from aspects of the present innovation.

The present innovation is not limited to any specific number or configuration of nodes **102** or blocks **112** in a rack **104**. According to one aspect, nodes **102** can be of different physical heights of form factors (e.g., 1U, 1.5U, 2U), and the described features can also be applied to nodes **102** having different widths and depths (into the rack), with some extensions made and/or lateral modifications to the placement of cooling subsystem conduits, as needed to accommodate the different physical dimensions. As a specific example, node **102***i* is depicted as having a larger node enclosure **107'** (with corresponding different dimensions of heat-generating functional components **106'**) of a different number of rack units in physical height (e.g., 2U) that differs from the heights (e.g., 1U) of the other nodes **102***a*-**102***h* and **102***j*-**102***k*. RIHS **100** can include blocks **112** or nodes **102** selectably of a range of discrete rack units. Also, different types of IT components can be provided within each node **102**, with each node possibly performing different functions within RIHS **100**. Thus, for example, a given node **102** may include one of a server module, a power module, a control module, or a storage module. In a simplest configuration, the nodes **102** can be individual nodes operating independent of each other, with the RIHS **100** including at least one rack-level controller (RC) **116** for controlling operational conditions within the RIHS **100**, such as temperature, power consumption, communication, and the like. Each node **102** is then equipped with a node-level controller (NC) **118** that communicates with the rack-level controller **116** to provide localized control of the operational conditions of the node **102**. In the more standard configuration of a DL RIHS **100**, and in line with the described embodiments, RIHS **100** also includes block-level controllers (BCs) **114**, communicatively coupled to the rack-level controller **116** and performing block-level control functions for the LC nodes within the specific block. In this configuration, the nodes **102** are arranged into blocks **112**, with each block **112** having one or more nodes **102** and a corresponding block-level controller **114**. Note the blocks do not necessarily include the same number of nodes, and a block can include a single node, in some implementations.

A Direct-Interface Liquid Cooling (DL) subsystem (generally shown as being within the RIHS and labelled herein as **120**) provides direct-intake/flow of cooling liquid to heat-generating functional components **106** via a liquid rail **124** under the control of rack-level controller **116**, block-level controllers **114**, and/or node-level controllers **118**, in some embodiments. Rack-level controller **116** controls a supply valve **126**, such as a solenoid valve, to allow cooling liquid, such as water, to be received from a facility supply **128**. The cooling liquid is received from facility supply **128** and is passed through liquid filtration node **102***l* before being passed through supply conduit **130** of liquid rail **124**. Each block **112***a*, **112***b* receives a dynamically controlled amount of the cooling liquid via block-level dynamic control valve **132**, such as a proportional valve. Return flow from each block **112***a*, **112***b* can be protected from backflow by a block check valve **133**. The individual needs of the respective nodes **102***a*-**102***d* of block **112***a* can be dynamically provided by respective node-level dynamic control valves **134**, controlled by the block-level controller **114**, which control can, in some embodiments, be facilitated by the node-level controllers **118**. In one or more embodiments, at node level the control valves **134** can be shutoff valves for emergency shutoff for leaks rather than dynamically controlled for thermal optimization. In addition to allocating cooling liquid in accordance with cooling requirements (which can be optimized for considerations such as performance and economy), each of the supply valve **126** and/or dynamic control valves **132**, **134** can be individually closed to mitigate a leak. A check valve **136** is provided between each node **102***a*-**102***j* and a return conduit **138** of the liquid rail **124** to prevent a backflow into the nodes **102***a*-**102***j*. The return conduit **138** returns the cooling liquid to a facility return **140**.

To support the temperature control aspects of the overall system, RIHS **100** includes temperature sensors **101** that are each located within or proximate to each node **102***a*-**102***j*, with each temperature sensor **101** connected to the node-level controller **118** and/or the corresponding block-level controller **114**. Temperature sensors **101** operate in a feedback control loop of the liquid cooling system **122** to control the amount of liquid flow required to cool the nodes **102***a*-**102***j*. In one or more embodiments, the rack-level controller **116** can coordinate performance constraints to block-level controllers **114** and/or node-level controllers **118** that limit an amount of heat generated by the heat-generating functional components **106** to match a heat capacity of the flow of cooling liquid in DL subsystem **122**. Alternatively or in addition, the rack-level controller **116** can coordinate cooling levels to block-level controllers **114** and/or node-level controllers **118** that in turn control the dynamic control valves **132**, **134** for absorption and transfer of the heat generated by the heat-generating functional components **106** by the DL subsystem **122**. In one or more embodiments, support controllers such as a Liquid Infrastructure Management Controller (LIMC) **142** can perform management and operational testing of DL subsystem **122**. LIMC **142** can monitor pressure sensors **144** and liquid sensors **146** to detect a leak, to validate operation of a dynamic control valves **132**, **134** or shut-off valves such as supply valve **126**. LIMC **142** can perform closed-loop control of specific flow rates within the RIHS **100**.

DL nodes **102***a*-**102***j* can include other components **108** such as a hard drive device (HDD) that does not require DL cooling but could be damaged by moisture from the DL subsystem **122**. A leak containment barrier **193** is configured with a trough **194** that underlays a portion of the system of conduits **143** of the LC node **102***a*-**102***j*. The trough **194** forms a drain path **191** to a drain port **195** of the chassis **110**. A leak control subsystem **196** includes a cascading gutter structure of drain conduits **197** originating from each trough **194** of a respective LC node **102***a*-**102***j* of the RIHS **100**. An absorbent material **192** can be positioned to absorb and hold at least an initial portion of any liquid that leaks in the leak containment barrier **193**. The trough **194** can direct even a small, slow leak to accumulate in a low portion for detection purposes. In one or more embodiments, the node-level liquid sensor **146** is exposed to the absorbent material **192** to detect a presence of liquid within the absorbent material **192**. For example, a pair of electrical conduits **146***a*, **146***b* can be inserted within the absorbent material and separated by a volume of the absorbent material **192**. An electrical current passes from a first conduit **146***a* to a second conduit **146***b* only when the absorbent material has absorbed a minimum threshold supply of leaked fluid.

The drain conduits **197** converge into a collection structure **198** that receives leaked liquid that flows through the cascading gutter structure. LIMC **142** is in communication with the at least one liquid sensor **146** that triggers a closing of one or more shutoff valve **132**, **134** in response to a corresponding liquid sensor **146** detecting a liquid leak in the RIHS **100**. In one or more embodiments, LIMC **142** is in communication with the node-level, block-level, and rack-level liquid sensors **146**. LIMC **142** associates a leak with a containment solution **186**. LIMC **142** triggers closure of one or more shutoff valves **126**, **132**, and **134** to effect the containment solution **186** in response to the detected presence of liquid in the collection structure.

FIGS. **2-3** illustrate example LC node **200** of example DL RIHS **100** of FIG. **1** having a node enclosure **207** insertable into a block chassis **210**. For purposes of description, node **200** is a server IHS that includes processing components or central processing units (CPUs), storage devices, and other components. LC node **200** includes cooling subsystem (generally shown and represented as **220**) that includes a liquid-to-liquid manifold **242** to cool heat-generating functional components **206** by heat transfer from liquid provided by node-level supply conduit **244**, and return conduit **246**, according to one or more embodiments. Node-level supply conduit **244** and return conduit **246** are appropriately sized and architecturally placed relative to the other components and the dimensionality (i.e., width, height, and depth/length) of LC node **200** to permit sufficient cooling liquid to pass through the interior of LC the node **200** to remove the required amount of heat from LC node **200** in order to provide appropriate operating conditions (in terms of temperature) for the functional components located within LC node **200**. Liquid-to-liquid manifold **242** can include CPU cold plates **248** and voltage regulator cold plates **250**. A sled assembly grab handle **252** can be attached between CPU cold plates **248** for lifting LC node **200** out of block chassis **210**. A return-side check valve **254** of the return conduit **246** can prevent facility water from back-feeding into LC node **200** such as during a leak event. Flex hose links **256** in each of node-level supply conduit **244** and return conduits **246** can reduce insertion force for sleds into block chassis **210**. Sled emergency shutoff device **234** interposed in the supply conduit **244** can be a solenoid valve that closes in response to input from a hardware circuit during a sled-level leak detection event. With particular reference to FIG. **3**, node-level carrier **258** received in node enclosure **207** can incorporate the leak containment barrier **293** to protect storage device **262**. In the illustrative example illustrated by FIG. **2**, LC node **200** is oriented horizontally and is viewed from above. In one or more embodiments node-level carrier **258** is configured to route leaked cooling liquid away from storage device **262** when oriented vertically.

According to one aspect, support surface **294** of node-level carrier **258** incorporates a vibration absorbing material that can be integral to structural portions of the node-level carrier **258**. In one or more embodiments, top vibration absorbing component **295**, such as a double-sided, adhesive backed, foam strip, can provide an attachment of storage devices **262** to the node-level carrier **258**. In one or more embodiments, bottom vibration absorbing component **296**, such as a double-sided, adhesive backed, foam strip, can provide an attachment of node-level carrier **258** to node enclosure **207**. The vibration absorbing material isolates sources of vibration to prevent the vibration from constructively amplifying to the point of impairing performance or damaging IT equipment. For example, a storage drive **262** can include a disk drive that creates a vibration during a repeated sequence of sector reads or writes. As another example, the liquid cooling system can include vibrations originating from movement/flow of the fluid moving and/or flow volume control. As yet an additional example, air movers can create vibrations. With these vibration absorbing materials integrated into the design, node-level carrier **258** protects the storage devices **262** from vibrations originating at or otherwise delivered to storage devices **262**.

FIGS. **4-6** illustrate different exterior and rear views of an example assembled DL RIHS **400**. DL RIHS **400** includes rack **404**, which is a physical support structure having an exterior frame and attached side panels to create cabinet enclosure **464** providing interior chassis receiving bays (not shown) within which a plurality of individual node chasses (or sleds) **207** of functional IT nodes, such as LC node **200** of FIG. **2**, are received. In the description of the figures, similar features introduced in an earlier figure are not necessarily described again in the description of the later figures. In an exemplary embodiment, the cooling liquid is received from a facility supply **128** (of FIG. **1**) via below rack (e.g. ground level or below floor) connections **680***a*. In one or more embodiments, the cooling liquid is received via an above-rack (and possibly in ceiling) connections **680***b*.

FIGS. **4-6** specifically illustrate exterior views of rack **404** of example DL RIHS **100**. As illustrated, rack **404** includes opposing side panels **466**, attached to a top panel **468** (and bottom panel—not shown) to create the main cabinet enclosure **464** that includes multiple chassis receiving bays for housing LC nodes **102/200**. The created cabinet enclosure **464** includes a front access side (not shown) and a rear side. The front access side provides access to the chassis receiving bays created within the main cabinet enclosure **464** for receiving LC nodes **102** (of FIG. **1**) into rack **404**. Attached to the rear ends of the main opposing side panels **466** are opposing side panel extensions **472**. A louvered rear door **474** is hinged (or otherwise attached) to one of the side panel extensions **472** and includes a latching mechanism for holding the door **474** in a closed position, where in a closed position is relative to the otherwise open space extending laterally between opposing side panel extensions **472**. Side panel extensions **472** and louvered rear door **474** provide an extension to main cabinet enclosure **464** for housing, covering/protecting, and providing access to the modular, scalable liquid rail **424** of a liquid cooling subsystem **422** that provides liquid cooling to each LC node **102** (of FIG. **1**) inserted into the chassis of the main cabinet enclosure **464**.

FIGS. **5-6** illustrate an embodiment in which rear pipe covers **476** can protect portions of liquid rail **324**, and specifically Modular Liquid Distribution (MLD) conduits **478**, from inadvertent damage as well as containing any leaks from being directed at sensitive functional components **106** (of FIG. **1**). FIG. **5** illustrate that the rear pipe covers **476** can be vertically sized to correspond to MLD conduits **478**.

FIG. **7** illustrates a more detailed view of the internal makeup of the rails and other functional components of a cooling subsystem **722** of example RIHS **700**. According to one embodiment, cooling subsystem **722** also includes air movers and/or other devices to provide for forced air cooling in addition to the direct interface liquid cooling. As shown by FIG. **7**, at least one fan module **782** is rear mounted to a block liquid manifold **789** in which an air-to-liquid heat exchanger (or radiator) **788** is incorporated. The fan module **782** provides air movement through the chassis **710** and/or node enclosure **708** of the node **702** as well as through the air-to-liquid heat exchanger **788**. Each block liquid manifold **789** includes a supply bypass tube **790** and a return bypass tube **791** through which a dynamically determined amount of cooling liquid is directed into the respective node **702** while allowing a bypass flow to proceed to the next node/s **702** in fluid path of the intake flow. Fan module **782** includes apertures **747** through which the supply and return bypass tubes **790**, **791** are extended, in one embodiment. Nodes **702** are connected into the back side of the block liquid manifold with the ends of intake and exhaust liquid transfer conduits in sealed fluid connection with bypass tubes **790** and **791** respectively.

FIG. **8** illustrates a more detailed view of the interconnections of the liquid cooling subsystem, at a node level and rack level within an example DL RIHS **800**. As shown, RIHS **800** is configured with LC nodes **802*a*-802*e*** arranged in blocks (e.g., block 1 comprising **802*a*-802*c***) and which are cooled in part by a liquid cooling system having a liquid rail comprised of MLD conduits, and in part by a subsystem of air-liquid heat exchangers, can be configured with heat-generating functional components **806** and that are cooled at least in part by a system of MLD conduits **878*a*-878*b***, according to one or more embodiments. Illustrated within nodes **802** are heat-generating functional components **806**, such as processors, voltage regulators, etc., which emit heat during operation and or when power is applied to the component, such that the ambient temperature increases around the component, and within the node, and eventually within the block, and ultimately DL RIHS **800**, during standard operation. To mitigate heat dissipation (and effects thereof), and to maintain the RIHS, block, node, and functional components within proper operating temperatures, DL RIHS **800** is configured with a DL subsystem **822**. DL subsystem **822** includes a rack level network of liquid propagating pipes, or conduits that are in fluid communication with individual node level networks of liquid propagating conduits. Additionally, DL subsystem **822** collectively facilitates heat absorption and removal at the component level, the node level, the block level, and/or the rack level. The rack-level network of conduits includes a modular arrangement of a liquid rail **824** formed by more than one node-to-node MLD conduit **878** *a*-**878*b*** spanning (or extending) between LC nodes **802** provisioned in rack **804**.

At the top position of RIHS **800**, a block chassis **810** is received in a block chassis receiving bay **870*a*** of rack **804**. Within block chassis **810**, a first node **802*a*** received in a first node receiving bay **809*a*** of the rack **804** has a vertical height of one rack unit (1U). A rack unit, U or RU as a unit of measure, describes the height of electronic equipment designed to mount in a 19-inch rack or a 13-inch rack. The 19 inches (482.60 mm) or 13 inches (584.20 mm) dimension reflects the horizontal lateral width of the equipment mounting-frame in the rack including the frame; the width of the equipment that can be mounted inside the rack is less. According to current convention, one rack unit is 1.75 inches (44.45 mm) high. A second node **802*b*** received in a second node receiving bay **809*b*** of the rack **104** (of FIG. **1**) has a vertical height of 1U. A third node **802*c*** received in a third node receiving bay **809*c*** of the rack **804** has a vertical height of 1U. A fourth node **802*d***, infrastructure node **802*b***, is received in a second block chassis receiving bay **870*b*** of rack **804** and has a vertical height of 1U. Infrastructure node **802*b*** can contain functional components such as a rack-level controller **816**. A fifth node **802*e*** is received in a third chassis receiving bay **870*c*** and has a vertical height of 2U. A sixth node **802*f***, which provides a Rack Filtration Unit (RFU) **871**, is received in a fourth block chassis receiving bay **870*d*** of the rack **804**. Infrastructure node **802** and RFU **871** are examples of nodes **802** that may not require liquid cooling. A cascading liquid containment structure **803** is received in a fifth chassis receiving bay **870*e*** and includes liquid sensor **897**.

MLD conduits **878*a*** of 1U can be used to connect nodes of 1U vertical spacing. Because of the additional 1U separation of LC nodes **802*c*** and **802*e*** by inclusion of infrastructure node **802*d***, MLD conduit **878*b*** between the third and fifth nodes **802*c*-802*d*** is dimension 2U to accommodate the increased spacing. MLD conduits **878** *a*-**878*b*** can thus support different heights (1U to NU) of IT components.

Each MLD conduit **878** *a*-**878*b*** includes first and second terminal connections **883**, **884** attached on opposite ends of central conduit **885** that is rack-unit dimensioned to seal to a port of LC node **802** and enable fluid transfer between a port of a selected LC node **802** and a port of an adjacent LC node **802**. In FIG. **8**, facility supply **828** and facility return **840** are respectively located at the intake end of liquid rail **824** and the exhaust end of liquid rail **824**. The actual location of facility supply **828** and facility return **840** can be reversed. Alternatively, facility supply **828** and facility return **840** can be located above the RIHS **800** or both conduits can be located on opposite sides of the RIHS **800** in alternate embodiments.

Liquid cooling subsystem **822** includes a liquid infrastructure manager controller (LIMC) **842** which is communicatively coupled to block liquid controllers (BLCs) **887** to collectively control the amount of cooling liquid that flows through the RIHS **800** and ultimately through each of the nodes **802** in order to effect a desired amount of liquid cooling at the component level, node level, block level, and rack level. For clarity, LIMC **842** and BLCs **887** are depicted as separate components. In one or more embodiments, the liquid control features of the LIMC **842** and BLCs **887** can be incorporated into one or more of the rack-level controller **816**, block-level controllers **820**, and the node-level controllers **818**. As illustrated in FIG. **1** and previously described, each of the LIMC **842** and BLCs **887** are connected to and respectively control the opening and closing of flow control valves that determine the amount of flow rate applied to each block and to each node within the specific block. During cooling operations, one of LIMC **842** and BLC **887** causes a specific amount of liquid to be directly injected into the intake conduits of the LC node **802**, which forces the cooling liquid through the system of conduits within the LC node **802** to the relevant areas and/or functional components/devices inside the nodes **802** to absorb and remove heat away from the inside of the node and/or from around the components within the node.

As another aspect, the present disclosure provides a modular approach to utilizing air-to-liquid heat exchanger **888** with quick connection and is scalable in both 1U and 2U increments. In one or more embodiments, DL cooling subsystem **822** can include a plurality of air-to-liquid (or liquid-to-air) heat exchangers **888** that facilitate the release of some of the heat absorbed by the exhaust liquid to the surrounding atmosphere around the RIHS **100** (of FIG. **1**). Air-to-liquid heat exchangers **888** can be integral to block liquid manifold **889** that, along with the MLD conduits **878** *a*-**878***b*, form scalable liquid rail **824**. One aspect of the present disclosure is directed to providing scalable rack-mounted air-to-liquid heat exchanger **888** for targeted heat rejection of rack-mounted equipment to DL cooling subsystem **822**. Hot air **899** from auxiliary components, such as storage device **808**, would be pushed through the air-to-liquid heat exchanger **888**, and the resulting energy would transfer to liquid rail **824** and be rejected to a facility cooling loop, represented by the facility return **840**.

RIHS **800** can include variations in LC node **802** that still maintain uniformity in interconnections along liquid rail **824** formed by a chassis-to-chassis modular interconnect system of MLD conduits **878** *a*-**878***b*. With this scalability feature accomplished using MLD conduits **878** *a*-**878***b*, cooling subsystem **822** of the RIHS **800** allows each block chassis **810** to be a section of a scalable manifold, referred herein as liquid rail **824**, eliminating the need for a rack manifold. The scalability of liquid rail **824** enables flexible configurations to include various permutations of server and switch gear within the same rack (rack **804**). MLD conduits **878** *a*-**878***b* can comprise standardized hoses with sealable (water tight) end connectors. Thus, the rack liquid flow network can encompass 1 to N IT chassis without impacting rack topology, space constraints, and without requiring unique rack manifolds. Additionally, according to one aspect, the MLD conduits are arranged in a pseudo daisy chain modular configuration, which allows for unplugging of one MLD conduit from one rack level without affecting liquid flow to and cooling of other rack levels.

The system of conduits extending from node intake valve **834** into each LC node **802** enables each LC node **802** to engage to block liquid manifold **889**. Block chassis **810** or node enclosure **807** of each LC node **102** provides the intake and exhaust conduit connections to engage to respective terminals of MLD conduits **878** *a*-**878***b* within the MLD network provided by liquid rail **824**. For example, where nodes **802** are designed as sleds, node enclosure **807** would be a sled tray, and each block would then include more than one sled tray received into block chassis **810**, forming the extensions of block liquid manifold **889**. Alternatively, the node enclosure **807** can be a single node chassis such as one of nodes **802***c*-**802***f*.

Supply and return bypass tubes **890**, **891** of each block liquid manifold **889** are connected by MLD conduits **878** *a*-**878***b* to form supply rail conduit **830** and return rail conduit **838**. For clarity, FIG. **8** illustrates the return rail conduit **838** separately. Liquid rail **824** enables multiple types of devices to be coupled together, each receiving an appropriately controlled portion of cooling liquid capacity. In one embodiment, liquid cooling subsystem **822** is passively pressurized by attaching MLD supply conduit **892***a* to facility supply **828** and an MLD return conduit **892***b* to facility return **840**. Liquid flow from supply rail conduit **830** to return rail conduit **838** of liquid rail **824** can be controlled based upon factors such as a temperature of the liquid coolant, detected temperature within LC nodes **802**, air temperature inside or outside of DL RIHS **800**, etc.

In an exemplary embodiment, the scalable rack manifold provided by liquid rail **824** is formed in part by MLD conduits **878** *a*-**878***b* that run vertically in the back of the RIHS **800** with quick disconnects on the front and rear face of block liquid manifold **889** that allows for IT/infrastructure equipment respectively to be plugged into both front and back sides of the block liquid manifold **889**. For example, LC nodes **802**, such as server modules, can plug into the front side and fan modules **882** can plug onto the back side of block liquid manifold **889**. This also allows for other liquid cooled devices such as LC Power Distribution Units (PDUs) to be plugged into the cooling liquid supply rail conduit **830** and return rail conduit **838** of liquid rail **824**. Thereby, a rack hot pluggable cooling interface is created for any rack-mounted equipment.

Cooling subsystem **822** can support an embedded liquid-to-liquid heat exchanger manifold **841**, such as in LC node **802***c*. Node liquid-to-liquid heat exchangers are provided for rejecting heat from one fluid source to a secondary source. One aspect of the present disclosure solves the problems that many shared-infrastructure IT systems (e.g., blade chassis) do not have adequate space to accommodate a liquid-to-liquid heat exchanger. Unlike with generally-known systems that rely upon liquid heat transfer having to exchange heat with an external liquid-to-liquid heat exchanger, the present disclosure enables on-rack liquid-to-liquid heat exchanger that does not require any of the vertical chassis space. Additionally, the present disclosure provides these benefits without requiring a central distribution unit (CDU), which takes up datacenter floor space. One aspect of the present disclosure provides embedded heat exchanger manifold **841** having a common heat transfer plate and a shared bulk header to create a combined liquid distribution manifold that includes a secondary liquid coolant for absorbing heat through the shared bulk header. In particular, the combined embedded heat exchanger manifold **841** rejects heat within shared node enclosure **807** such as node **802***c* to a secondary liquid coolant. Internal node supply **844** and return conduits **846** of a manifold built on top of a heat exchanger core allow heat transport within manifold **841**. In one embodiment, closed system pump **898** can use a first coolant to cool a high thermal energy generating functional component such as a CPU or voltage regulator.

Additionally, the liquid cooling subsystem **822** also includes a filtration system or unit **871**, which prevents chemical impurities and particulates from clogging or otherwise damaging the conduits as the fluid passes through the network of conduits. According to one aspect of the disclosure, liquid cooling subsystem **822** provides RFU **871** in fluid connection with the intake pipes from facility supply **828**. In at least one embodiment, RFU **871** includes a sequenced arrangement of liquid filters within a full-sized sled that can be removably inserted by an end user into one of the receiving slots of rack **804**. In one embodiment, the RFU **871** is located on an infrastructure sled having rack-level controllers and other rack-level functional components. In at least one embodiment, the entirety of the sled is filed with components associated with RFU **871**. Thus, it is appreciated that the RFU **871** may occupy the entire area of one vertical slot/position within the chassis. Alternate locations of the RFU **871** can also be provided, in different embodiments, with an ideal location presenting the intake port of the RFU **871** in close proximity to a connection to facility supply **828** to directly receive the facility supply **828** prior to the liquid being passed into the remainder of the conduits of the liquid cooling subsystem **822**. It is appreciated that if the system was capable of completing all heat exchange within the rack, then sealing the rack would be feasible and would reduce and/or remove any requirements for filtration and/or allocation of rack space for RFU **871**.

Liquid cooled compute systems use the high heat transport capacity of water. However, the disclosure recognizes and addresses the fact that with liquid introduced into an electronic enclosure, there is a potential for leaks that can cause catastrophic system failure. Also, in some instances, a leak can create an electronic short with a resulting exothermal reaction causing permanent damage to the DL RIHS **800**. To mitigate such risks, as one design feature, node-level HDD carrier or leak containment barrier **893** can include a trench/gutter system or trough **894**. In one embodiment, the gutter system can also incorporate an absorbent material that can accumulate sufficient amounts of liquid from small leaks to enable external sensing of the leak. Advantageously, the leak containment barrier **893** can also be thermally conductive to serve as a heat sink for components such as storage devices **808**. In one embodiment, another leak detection solution that can be incorporated into the LC node **802** involves use of a solenoid to create an event when additional current is applied, due to water pooling around the solenoid. Barriers on leak containment barrier **893** can be specifically designed to contain a liquid leak and assist in funneling the liquid through the gutter system. Liquid rail **824** can also be provided with leak containment and detection. In one or more embodiments, removable pipe covers **876** are sized to be mounted around respective MLD conduits **878** *a*-**878***b* and can include liquid sensors **897** for automatic alerts and shutdown measures.

In one or more embodiments, DL RIHS **800** further incorporates a node-level liquid containment structure **803** with a cascading drain runoff tubing network **896** to a rack-level cascading liquid containment structure **895**. In one or more embodiments, the DL RIHS **800** further incorporates leak detection command such as partial or complete automated emergency shutdown. Liquid sensors (LS) **897** at various cascade levels can identify affected portions of DL RIHS **800**. Containment and automatic shutoff can address the risks associated with a leak developing in the DL cooling system **822**.

FIG. **9** illustrates a more detailed view of DL subsystem **920** associated with example DL RIHS **900**. Within DL RIHS **900**, each LC node **902***a*, **902***b* includes chassis **910** received in a respective chassis-receiving bay **970** of rack **904**. Each LC node **902***a*, **902***b* contains heat-generating functional components **906**. Each LC node **902***a*, **902***b* is configured with a system of internal supply conduit **944** and return conduit **946**, associated with embedded heat exchanger manifold **941**. Embedded heat exchanger manifold **941** receives direct intake/flow of cooling liquid to regulate the ambient temperature of LC node **902***a*, **902***b*. A node-level dynamic control valve **934** and node-level return check valve **936** control an amount of normal flow and provide shutoff and/or otherwise mitigate a leak. Cooling subsystem **920** provides cooling to heat-generating functional components **906** inside the LC node **902***a*, **902***b* by removing heat generated by heat-generating functional components **906**. Liquid rail **924** is formed from more than one node-to-node, MLD conduit **978** between more than one LC node **902***a*, **902***b* within in rack **904**. MLD conduits **978** includes first terminal connection **983** and second terminal connection **984**. First terminal connection **983** and second terminal connection **984** are attached on opposite ends of central conduit **985**. Central conduit **985** is rack-unit dimensioned to directly mate and seal to and enable fluid transfer between a selected pair of rail supply ports **917** and/or rail return ports **919** of a selected LC node **902***a* and an adjacent LC node **902***b*.

The cooling subsystem **920** includes block liquid manifolds **989** mountable at a back side of the rack **904**. Each block liquid manifold has at least one rail supply port **917** and at least one rail return port **919** on an outside facing side of the block liquid manifold **989**. The at least one rail supply port **917** and the at least one rail return port **919** respectively communicate with at least one block supply port **921** and a block return port **923** on an inside facing side of the block liquid manifold **989**. LC nodes **902** are insertable in receiving bays **970** of rack **904** corresponding to locations of the mounted block liquid manifolds **989**. Block supply ports **921** and block return ports **923** of the LC nodes **902** and an inside facing portion of the corresponding block liquid manifold **989** are linearly aligned. The linear alignment enables direct sealing, for fluid transfer, of the lineally aligned inside manifold supply ports **925** and return ports **927** to the inside facing portion of the block liquid manifold **989**. In one or more embodiments, block supply port **921** sealed to the internal manifold supply port **925** communicates via supply bypass tube **990** to two rail supply ports **917**. Block return port **923** sealed to internal manifold return port **927** communicates via return bypass tube **991** of the respective block liquid manifold **989** to two rail return ports **919**. Fan modules **982** mounted respectively onto back of block liquid manifold **989** have apertures to expose rail supply and return ports **917**, **919**. Additionally, fan modules **982** draw hot air **999** from LC nodes **902** through an air-liquid heat exchanger **988** in block liquid manifold **989**.

In one or more embodiments, supply liquid conduit **992***a* is attached for fluid transfer between facility supply **928** and rail supply port **917** of block liquid manifold **989** of RIHS **900**. A return liquid conduit **992***b* can be attached for fluid transfer between rail return port **919** of block liquid manifold **989** and facility return **940**. FIG. **9** further illustrates that the fluid connection to facility supply **928** includes RFU **971**. To prevent contamination or causing damage to cooling subsystem **920**, RFU **971** is received in bay **970** of rack **904** and includes one of two input ports **929** connected via supply liquid conduit **992***a* to facility supply **928**. The RFU **971** includes one of two output ports **931** that is connected to MLD conduit **978** of supply rail conduit **930**. Liquid rail **924** also includes return rail conduit **938**. RFU **971** controls two external emergency shutoff valves **933** for flow received from the input port **929** that is provided respectively via hot-pluggable disconnects **935** to two replaceable filtration subunits (“filters”) **937**. The flow of cooling liquid flows in parallel to two replaceable filtration subunits **937**, automatically diverting to the other when one is removed for replacing. Thereby, filtration and cooling of RIHS **900** can be continuous. Back-flow is prevented by check valve **939** that allows normal flow to exit to output port **931**. Differential pressure sensor **947** measures the pressure drop across filters”) **937** and provides an electrical signal proportional to the differential pressure. According to one aspect, a LINC

942 can determine that one filter 937 is clogged if the differential pressure received from differential pressure sensor 944 falls below a pre-determined value.

In one or more embodiments, RIHS 900 can provide hot-pluggable server-level liquid cooling, an integrated leak collection and detection trough, and an automatic emergency shut-off circuit. At a block level, RIHS 900 can provide embedded air-to-liquid heat exchange, and dynamic liquid flow control. At a rack level, RIHS 900 can provide facility-direct coolant delivery, a scalable rack fluid network, a rack filtration unit, and automated rack flow balancing, and a service mode.

According to one embodiment, liquid rail 924 includes a series of secondary conduits, such as a supply divert conduit 997 and a return divert conduit 998, that provides a by-pass fluid path for each of MLD conduits 978. In operation, divert conduit 997 allows for the removal of corresponding MLD conduit 978, thus removing the flow of cooling liquid to the particular block of nodes, without interrupting the flow of cooling liquid to the other surrounding blocks of computer gear. For example, a particular MLD conduit 978 can be replaced due to a leak. For another example, a block liquid manifold 989 can be replaced. The inclusion of divert conduits 997, 998 thus enables rapid servicing and maintenance of block liquid manifold 989 and/or nodes within block chassis without having to reconfigure the MLD conduits 978. In addition, the RIHS 900 can continue operating as cooling liquid continues to be provided to the remainder of the blocks that are plugged into the liquid rail. Re-insertion of the MLD conduit 978 then reconnects the flow of cooling liquid to the block for normal cooling operations, and shuts off the diverted flow of cooling liquid. In an exemplary embodiment, the MLD conduits 978 provide a quick disconnect feature that interrupts flow when not fully engaged to a respective port 917, 919, 921, 923. Disconnection of an MLD conduit 978 interrupts flow in a primary portion of the liquid rail 924 for either supply or return, shifting flow through one or more divert conduits 997 to provide cooling liquid to the other block liquid manifolds 989. In one or more embodiments, a manual or active shutoff valve can interrupt flow on either or both of the primary or divert portions of the liquid rail 924.

In one or more embodiments, each LC node 902 can receive liquid cooling service from a corresponding block liquid manifold 928 as illustrated by FIG. 9. In one or more embodiments, one or more block liquid manifolds 928 provide liquid cooling service to a block chassis 910 that in turn quick connects to more than one LC node 902*a*, 902*b*. A node-receiving liquid inlet port 911 and a node-receiving liquid outlet port 913 are located at the rear section of one node-receiving slot 909*a*, 909*b* and positioned to be inwardly facing for blind mating to a node inlet and outlet ports 915, 917 of an LC node 902*a*, 902*b* inserted in the one node-receiving slot 909*a*, 909*b*. The system of internal supply conduit 944 and return conduit 946 supply cooling liquid through the node enclosure 907. The supply conduit 944 extends from a node inlet coupling 915, which in an exemplary embodiment is a male inlet coupling. The return conduit 946 terminates in a node outlet coupling 917, which in an exemplary embodiment is a male outlet coupling. The node inlet port 915 and the node outlet port 917 are positioned in an outward facing direction at a rear of the node enclosure 907. The node inlet port 915 and the node outlet port 917 are aligned to releasably seal to the respective inlet liquid port and outlet liquid port in the node-receiving slot 909*a*, 909*b*, for fluid transfer through the system of conduits 944, 946. A block supply plenum 975 and return plenum 976 can communicate for fluid transfer between the block liquid manifold 989 and each of the supported LC nodes 902*a*, 902*b*. Modulation or shutoff of cooling liquid at the block level can also be incorporated into the block supply plenum 975 and return plenum 976.

FIG. 10 illustrates a method 1000 of assembling a DL RIHS. In one or more embodiments, the method 1000 includes inserting a leak containment barrier in a node enclosure (block 1002). The method 1000 includes provisioning the node enclosure with heat-generating functional components (block 1004). The method 1000 includes attaching the system of conduits supplying cooling liquid through the node enclosure. The system of conduits includes a supply conduit extending from the node inlet coupling and a return conduit terminating in the node outlet coupling. A trough of the leak containment barrier underlays a portion of the system of conduits of the LC node and forms a drain path to a drain port of the node enclosure (block 1006). The method 1000 includes mounting the LC node insertably received in the one node-receiving slot of a rack having one or more node-receiving slots. Each slot has a front opening for node insertion and a rear section opposed to the front access for blind mating of the node inlet and outlet ports to a node-receiving liquid inlet port and a node-receiving liquid outlet port located at the rear section of one node-receiving slot. The node-receiving liquid inlet port and the node-receiving liquid outlet port are positioned to be inwardly facing to the LC node inserted in the one node-receiving slot (block 1008). Then method 1000 ends.

FIG. 11 illustrates a method 1100 of containing leaks in a DL RIHS. In one or more embodiments, the method 1100 includes a controller communicating with a liquid sensor to detect liquid received in a leak containment barrier that is leaked in a trough from a received system of conduits internal to a node enclosure of an LC node that is provisioned with a heat-generating computing component (block 1102). In one or more embodiments, the method 1100 includes, identifying which levels of leak detection sensors detected the leak from among a node-level sensors, one or more block-level sensors, and the rack-level sensor (block 1104) In an exemplary embodiment, an absorbent material is positioned to absorb and hold at least an initial portion of any liquid that leaks in the leak containment barrier. The node-level liquid sensor is exposed to the absorbent material to detect a presence of liquid within the absorbent material. In response to determining which levels of leak detection sensors detected the leak, method 1100 includes triggering shutoff of at least a lowest level shutoff valve that supplies cooling liquid to an area monitored by the identified sensor (block 1106). The method 1100 includes determining whether the containment solution applied was effective by determining whether an additional leak detection signal is subsequently received at a higher level sensor (decision block 1108). In response to determining the containment solution was effective in decision block 1108, the method 1100 ends. In response to determining the containment solution was not effective in decision block 1108, the method 1100 includes triggering a shutoff valve that supplies cooling liquid to the higher level area monitored by the higher level sensor (block 1110). Then method 1100 ends.

In an exemplary embodiment, the method 1000 can include receiving node (server), block and rack-level sensor signals as listed in Table 1200 in FIG. 12. In an exemplary embodiment, method 1000 can associate the sensor signals with rack-level scenarios and rack-level leak containment solutions as listed in Table 1300 in FIG. 13. In an exemplary embodiment, method 1000 can associate the sensor signals with block-level scenarios and block-level leak containment solutions as listed in Table **1400** in FIG. **14**. In an exemplary embodiment, the method **1000** can associate the sensor signals with node-level scenarios and node-level leak containment solutions as listed in Table **1500** in FIG. **1500**. In an exemplary embodiment, method **1000** can receive the sensor signals from sensors listed in Table **1600** in FIG. **16**.

In the above described flow charts of FIGS. **10-11**, one or more of the methods may be embodied in an automated manufacturing system or automated controller that performs a series of functional processes. In some implementations, certain steps of the methods are combined, performed simultaneously or in a different order, or perhaps omitted, without deviating from the scope of the disclosure. Thus, while the method blocks are described and illustrated in a particular sequence, use of a specific sequence of functional processes represented by the blocks is not meant to imply any limitations on the disclosure. Changes may be made with regards to the sequence of processes without departing from the scope of the present disclosure. Use of a particular sequence is therefore, not to be taken in a limiting sense, and the scope of the present disclosure is defined only by the appended claims.

One or more of the embodiments of the disclosure described can be implementable, at least in part, using a software-controlled programmable processing device, such as a microprocessor, digital signal processor or other processing device, data processing apparatus or system. Thus, it is appreciated that a computer program for configuring a programmable device, apparatus or system to implement the foregoing described methods is envisaged as an aspect of the present disclosure. The computer program may be embodied as source code or undergo compilation for implementation on a processing device, apparatus, or system. Suitably, the computer program is stored on a carrier device in machine or device readable form, for example in solid-state memory, magnetic memory such as disk or tape, optically or magneto-optically readable memory such as compact disk or digital versatile disk, flash memory, etc. The processing device, apparatus or system utilizes the program or a part thereof to configure the processing device, apparatus, or system for operation.

While the disclosure has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the disclosure. In addition, many modifications may be made to adapt a particular system, device or component thereof to the teachings of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiments disclosed for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope of the disclosure. The described embodiments were chosen and described in order to best explain the principles of the disclosure and the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method of assembling a direct-contact, liquid-cooled (DL) Rack Information Handling System (RIHS), the method comprising:

inserting a leak containment barrier in a node enclosure;

provisioning the node enclosure with heat-generating functional components; and

attaching a system of conduits supplying cooling liquid through the node enclosure and including a supply conduit extending from a node inlet coupling and a return conduit terminating in a node outlet coupling, wherein a trough of the leak containment barrier underlays a portion of the system of conduits of a liquid cooled (LC) node and forms a drain path to a drain port of the node enclosure; and

mounting the LC node insertably received in one node-receiving slot of a rack having one or more node-receiving slots, each slot having a front opening for node insertion and a rear section opposed to the front access configured for blind mating of the node inlet and outlet ports to a node-receiving liquid inlet port and a node-receiving liquid outlet port located at the rear section of one node-receiving slot and positioned to be inwardly facing to receive the couplings of the LC node inserted in the one node-receiving slot.

2. The method of claim **1**, further comprising:

connecting the system of conduits to a cooling liquid supply to receive direct contact of cooling liquid to regulate the ambient temperature of the LC node by absorbing and transferring heat from within the node via the cooling liquid.

3. The method of claim **1**, further comprising positioning the node inlet coupling and node outlet coupling and the inlet liquid port and outlet liquid port to be inwardly facing for blind mating to a node inlet and outlet ports of the inserted LC node.

4. The method of claim **1**, further comprising:

providing at least one shutoff valve to interrupt the supply flow of cooling liquid to the LC node; and

providing a node-level liquid sensor that detects liquid leaks in the trough structure and which is configured to communicate a signal identifying a presence of a liquid leak to at least one leak controller that triggers the at least one shutoff valve to close in response to receipt of the signal.

5. The method of claim **4**, wherein providing a node-level liquid sensor comprises:

positioning an absorbent material to absorb and hold at least an initial portion of any liquid that leaks in the leak containment barrier; and

exposing the node-level liquid sensor to the absorbent material to detect a presence of liquid within the absorbent material.

6. The method of claim **4**, wherein providing the node level liquid sensor comprises:

positioning an absorbent material to absorb and hold at least an initial portion of any liquid that leaks in the leak containment barrier; and

inserting a pair of electrical conduits inserted within the absorbent material, each conduit of the pair of electrical conduits separated by a volume of the absorbent material, wherein an electrical current passes from a first conduit to a second conduit only when the absorbent material has absorbed a minimum threshold supply of leaked fluid.

7. A method of containing leaks in a direct-contact, liquid-cooled (DL) Rack Information Handling System (RIHS), the method comprises:

communicating with a liquid sensor to detect liquid received in a leak containment barrier that is leaked in a trough from a received system of conduits internal to a node enclosure of a liquid cooled (LC) node that is provisioned with a heat-generating computing component; and

in response to detecting a leak:

identifying which levels of leak detection sensors detected the leak from among a node-level sensors, one or more block-level sensors, and a rack-level sensor;

in response to determining which levels of leak detection sensors detected the leak, triggering shutoff of at least a lowest level shutoff valve that supplies cooling liquid to an area monitored by the identified sensor; and

interrupting a supply flow of cooling liquid to the LC node by causing at least the lowest level shutoff valve to close.

8. The method of claim **7**, wherein:

an absorbent material is positioned to absorb and hold at least an initial portion of any liquid that leaks in the leak containment barrier; and

the node-level liquid sensor is exposed to the absorbent material to detect a presence of liquid within the absorbent material.

9. The method of claim **7**, further comprising:

determining whether the containment solution applied was effective by determining whether an additional leak detection signal is subsequently received at a higher-level sensor; and

in response to determining the containment solution was not effective, triggering a shutoff valve that supplies cooling liquid to a higher-level area monitored by the higher-level sensor.

10. A method of containing leaks in a direct-contact, liquid-cooled (DL) Rack Information Handling System (RIHS), the method comprising:

provisioning a liquid rail formed by more than one modular liquid distribution conduit connecting a rail supply and return port of adjacent LC nodes into a respective rail supply conduit and a respective rail return conduit;

communicating with a liquid sensor to detect liquid received in a leak containment barrier that is leaked in a trough from a received system of conduits internal to a node enclosure of a liquid cooled (LC) node that is provisioned with a heat-generating computing component; and

in response to detecting a leak, interrupting a supply flow of cooling liquid to the LC node by causing a shutoff valve to close.

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